09/830414

20/PRTS

JC08 Rec'd PCT/PTO 27 APR 2001

LIQUID CRYSTAL DISPLAY PANEL AND METHOD FOR MANUFACTURING THE SAME

TECHNICAL FIELD

The present invention relates to liquid crystal display panels used for flat panel displays for TV or computer images, and to methods for manufacturing the same. The present invention relates in particular to liquid crystal panel displays, in which the injection direction of the liquid crystal is optimized with respect to the rubbing direction of the alignment film, and to methods for manufacturing the same.

BACKGROUND ART

Conventionally, the injection of liquid crystal into an empty cell is generally performed by vacuum injection, for example. That is to say, an empty cell is formed by laminating two substrates with a sealing member, in which a portion for a liquid crystal injection port has been left open, the empty cell is evacuated, and then the liquid crystal injection port is brought into contact with a liquid crystal. Then, the liquid crystal is injected into the empty cell by returning the empty cell to atmospheric pressure.

It is known that the flow alignment pattern that results when the liquid crystal is introduced into the empty cell affects the alignment of the liquid crystal molecules. That is to say, intrinsic factors, such as the roperty of the liquid crystal to align with their long axis direction in the flow direction and the collective behavior of the liquid crystal, as well as extrinsic

factors, such as the injection direction of the liquid crystal etc., cause various flow alignments of the liquid crystal, and lead to one type of alignment disturbance. As one way to eliminate this flow alignment, the thermal equilibrium of the liquid crystal is subjected to a phase change from the nematic phase to the isotropic phase (isotropic fluid). More specifically, a phase transition is caused by heating the liquid crystal to a temperature above the nematic–isotropic phase transition temperature (N–I phase transition temperature T_{NI}), thereby eradicating the alignment order. As a result, the liquid crystal, which previously had an orderliness of a specific flow alignment pattern, becomes a disorderly isotropic fluid, whereby it is possible to eliminate the flow alignment. If the phase change is reversible with respect to temperature, then the phase can be changed back to nematic phase by cooling the liquid crystal after the heating process, introducing an alignment order, and this time, the liquid crystal is regulated by the alignment processing direction of the alignment film, so that it can be aligned in an alignment order as prescribed by this alignment processing direction.

However, there is the problem that, as a result of the effect of the macroscopically isotropic potential energy of the liquid crystal, flow alignment remains, even when the flow alignment pattern is heated above the phase transition temperature as described above.

As a result of not considering the relation between the alignment processing direction of the alignment film and the injection direction of the liquid crystal, there is the problem that there are variations in the injection

speed of the liquid crystal when the injection directions differ. This is due to the following reasons. As explained above, the liquid crystal molecules have the property that their long axis direction substantially matches the flow direction of the liquid crystal. Moreover, the surface of the alignment film is alignment processed to align the liquid crystal in a specific direction, and as a result, it exerts an alignment–regulating force, that attempts to line up the liquid crystal in the alignment processing direction. This results in one kind of resistance acting on the fluid (liquid crystal) flowing in a specific direction, depending on the surface condition of the alignment film. Thus, when the flow direction of the liquid crystal differs greatly from the alignment processing direction, the resistance due to the alignment–regulating force becomes great, and when the difference between the two directions is small, the resistance due to the alignment–regulating force becomes small. As a result, it seems that the injection speed differs depending on the injection direction of the liquid crystal.

On the other hand, flow alignment occurs also when there is an obstacle hindering the liquid crystal flow when injecting the liquid crystal. For example, in the case of IPS mode liquid crystal panels, a flow resistance results from structural elements with a large film thickness, such as electrodes having a plurality of bending points that extend in a predetermined direction while being bent in alternating directions at these bending points and are shaped like a chain of connected "V"s (so–called "<"–shaped electrodes), or the black matrix in color filters. That is to say, when the liquid crystal injection port is provided at a substrate side that is

parallel to the extension side of the electrodes, and the liquid crystal is injected from that liquid crystal injection port, then the flow direction of the liquid crystal is perpendicular to the extension direction of the electrodes. Therefore, the electrodes pose a large flow resistance for the flowing liquid crystal, and flow alignment and disclinations occur. Thus, there is the problem that when the regions between the electrode pairs for applying a transversal electric field are partitioned into a plurality of regions by dividing them at the bending points, the initial alignment in two neighboring regions does not match.

DISCLOSURE OF THE INVENTION

It is an object of aspects of the present invention to solve these conventional problems, and to present a liquid crystal display panel, in which the injection speed of the liquid crystal is made constant and the flow alignment is completely eliminated, as well as a manufacturing method for such a liquid crystal display panel.

The aspects of the present invention are based on the same or similar technical ideas. However, the various aspects of the present invention are realized by different working examples, so that in this specification, the aspects of the present invention are classified in a first aspect and a second aspect of the present invention, which are closely interrelated. The following is a description of these aspects of the present invention.

First Aspect of the Invention

In order to solve the afore–mentioned conventional problems, the inventors of the present invention investigated liquid crystal display panels and methods for manufacturing the same. As a result, the inventors found that it is possible to eliminate flow alignment occurring when injecting liquid crystal into an empty cell and to reduce variations in the injection speed by optimizing the injection direction of the liquid crystal with respect to the alignment direction in which the liquid crystal is aligned on the alignment film, thus arriving at the present invention.

(1) In order to attain the object of the present invention, a liquid crystal display panel in accordance with a first embodiment of the present invention includes a first substrate including a first alignment film that has been alignment processed in a first alignment processing direction; a second substrate arranged in opposition to the first substrate, including a second alignment film that has been alignment processed in a second alignment processing direction; and a liquid crystal layer arranged between the first substrate and the second substrate, having a twisted alignment structure in its initial alignment state, wherein a liquid crystal injection direction, in which liquid crystal material is injected to form the liquid crystal layer, is parallel to a direction dividing an intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles.

With this configuration, the occurrence of flow alignment when the liquid crystal is injected can be eliminated or suppressed. Moreover, it

becomes possible to suppress variations in the injection speed when injecting the liquid crystal. This is due to the following reasons. When the liquid crystal flows in a certain direction, the long axis direction of the liquid crystal molecules substantially matches the flow direction. Consequently, it seems that when injecting the liquid crystal, the liquid crystal molecules are arranged with their long axis direction in parallel to the injection direction. This means, they are in flow arrangement. However, since a first and a second alignment film that have been alignment processed in predetermined directions are formed on the inner side of the first and the second substrate, the injected liquid crystal is susceptible to the influence of the alignment–regulating force of these alignment films. Thus, this force attempts to align the liquid crystal molecules near the alignment films in the first and the second alignment processing direction respectively, and as a result, to attain a twisted structure, in which the first and the second alignment processing direction are rotated for a finite angle relative to one another. The smaller the discrepancy between the liquid crystal injection direction and the alignment processing directions is, the easier it will be to align the liquid crystal in the alignment processing direction, as becomes clear when looking at the energies involved. Consequently, by injecting the liquid crystal from a direction that is parallel to a direction dividing an intersection angle defined by the first alignment processing direction in the first alignment film and the second alignment processing direction in the second alignment film into two equal angles or substantially equal angles as in the above–described

configuration, the discrepancy between the liquid crystal injection direction and the alignment processing direction is made small, and regarding the energies involved, the liquid crystal can be easily aligned in the desired alignment. Thus, even when using an alignment film with small alignment–regulating force, it becomes possible to align the liquid crystal adequately in the desired direction, and to provide a liquid crystal display panel in which the occurrence of flow alignment is eliminated or suppressed.

(2) In order to attain the object of the present invention, a liquid crystal display panel in accordance with a second embodiment of the first aspect of the present invention includes a first substrate including a first alignment film that has been alignment processed in a first alignment processing direction; a second substrate arranged in opposition to the first substrate, including a second alignment film that has been alignment processed in a second alignment processing direction; and a liquid crystal layer arranged between the first substrate and the second substrate, having a twisted alignment structure in its initial alignment state, wherein a liquid crystal injection direction, in which liquid crystal material is injected to form the liquid crystal layer, is perpendicular to a direction dividing an intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles.

With this configuration, as in the configuration described in (1), it is possible to make the discrepancy between the liquid crystal injection direction and the alignment processing directions small, so that a liquid

crystal display panel is obtained, in which the occurrence of flow alignment is eliminated or suppressed.

(3) In order to attain the object of the present invention, a liquid crystal display panel in accordance with a third embodiment of the first aspect of the present invention includes a first substrate including a first alignment film that has been alignment processed in a first alignment processing direction; a second substrate arranged in opposition to the first substrate, including a second alignment film that has been alignment processed in a second alignment processing direction parallel to the first alignment processing direction; and a liquid crystal layer arranged between the first substrate and the second substrate, having a homogeneous alignment structure in its initial alignment state, wherein a liquid crystal injection direction, in which liquid crystal material is injected to form the liquid crystal layer, is arranged to be parallel to the first alignment processing direction and the second alignment processing direction.

When there is a discrepancy between the flow alignment direction of the liquid crystal directly after the injection and the alignment processing direction, then the occurrence of flow alignment is facilitated if the energy due to the collective behavior of the liquid crystal, which attempts to maintain the flow alignment, is larger than the alignment–regulating force of the alignment films, but with this configuration, the discrepancy between the alignment processing direction and the alignment direction of the liquid crystal molecules directly after the injection, which is a fundamental cause for flow alignment, is eliminated by matching the flow alignment (that is,

the liquid crystal injection direction) with the first and second alignment processing directions. Thus, a liquid crystal display panel can be obtained, in which flow alignment substantially does not occur.

It is possible to add the following structural features to the liquid crystal display panels according to the previous first to third embodiments.

For the first alignment film and the second alignment film, it is possible to use films, that have received their liquid crystal aligning ability in a rubbing process.

With this configuration, the alignment–regulating force of the first and second alignment films, which have been alignment processed by rubbing, is larger than that of alignment films that have been alignment processed by other methods. Thus, it is possible to align the liquid crystal in a predetermined alignment processing direction and to ensure a range of liquid crystal injection directions in which no flow alignment occurs, even when the angular difference between the liquid crystal injection direction and the alignment processing direction is large.

For the first alignment film and the second alignment film in this configuration, it is possible to use photosensitive alignment films including film molecules with photosensitive groups, which have received their liquid crystal aligning ability in a photoalignment process.

If the first alignment film and the second alignment film have been alignment processed in a photoalignment process, their alignment–regulating force is small, so that flow alignment occurs very easily, but also in this case, the occurrence of flow alignment is suppressed,

and a liquid crystal display panel that is aligned uniformly in a predetermined direction is attained.

Furthermore, in this configuration, the first alignment film and the second alignment film can be made of polyimide resin films.

Also, in this configuration, the first alignment film and the second alignment film can be made of films, in which a group of film molecules including a straight carbon chain is bonded / fixed to a surface of the substrates with siloxane bonds.

Furthermore, in this configuration, the first alignment film and the second alignment film can be made of monomolecular adsorption films or polymer adsorption films.

(4) A method for manufacturing a liquid crystal display panel corresponding to the first embodiment of the present invention includes an alignment film formation step of forming a first alignment film on a first substrate, and a second alignment film on a second substrate arranged in opposition to the first substrate; an alignment processing step of alignment processing the first alignment film in a first alignment processing direction and alignment processing the second alignment film in a second alignment processing direction; a sealing member formation step of forming on either the first substrate or the second substrate a frame–shaped sealing member having an open portion serving as a liquid crystal injection port; an aligning step of aligning the pair of substrates together at a predetermined spacing, such that the first alignment film and the second alignment film are arranged in opposition to one another, and the first alignment processing

direction and the second alignment processing direction rotated for a finite angle with respect to one another; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal layer having a twisted alignment structure in its initial alignment state; wherein an aperture direction of the liquid crystal injection port in the sealing member formation step is parallel to a direction dividing an intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles, and wherein the liquid crystal injection direction when injecting the liquid crystal material through the liquid crystal injection port in the liquid crystal injection step is parallel to the direction dividing the intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles.

(5) A method for manufacturing a liquid crystal display panel corresponding to the second embodiment of the present invention includes an alignment film formation step of forming a first alignment film on a first substrate, and a second alignment film on a second substrate arranged in opposition to the first substrate; an alignment processing step of alignment processing the first alignment film in a first alignment processing direction and alignment processing the second alignment film in a second alignment processing direction; a sealing member formation step of forming on either the first substrate or the second substrate a frame–shaped sealing member having an open portion serving as a liquid crystal injection port; an aligning

step of aligning the pair of substrates together at a predetermined spacing, such that the first alignment film and the second alignment film are arranged in opposition to one another, and the first alignment processing direction and the second alignment processing direction rotated for a finite angle with respect to one another; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal layer having a twisted alignment structure in its initial alignment state; wherein an aperture direction of the liquid crystal injection port in the sealing member formation step is perpendicular to a direction dividing an intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles, and the liquid crystal injection direction when injecting the liquid crystal material through the liquid crystal injection port in the liquid crystal injection step is perpendicular to the direction dividing the intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles.

(6) A method for manufacturing a liquid crystal display panel corresponding to the first embodiment of the present invention includes an alignment film formation step of forming a first alignment film on a first substrate, and a second alignment film on a second substrate arranged in opposition to the first substrate; an alignment processing step of alignment processing the first alignment film in a first alignment processing direction and alignment processing the second alignment film in a second alignment

processing direction; a sealing member formation step of forming on either the first substrate or the second substrate a frame–shaped sealing member having an open portion serving as a liquid crystal injection port; an aligning step of aligning the pair of substrates together at a predetermined spacing, such that the first alignment film and the second alignment film are arranged in opposition to one another, and the first alignment processing direction and the second alignment processing direction are arranged to be parallel or substantially parallel to one another; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal layer having a homogeneous alignment structure in its initial alignment state; wherein an aperture direction of the liquid crystal injection port in the sealing member formation step is parallel to the first alignment processing direction and the second alignment processing direction, and the liquid crystal injection direction when injecting the liquid crystal material through the liquid crystal injection port in the liquid crystal injection step is parallel to the first alignment processing direction and the second alignment processing direction.

With the embodiments described in (4), (5) and (6), variations in the injection speed when injecting the liquid crystal can be suppressed and a liquid crystal display panel with uniform alignment and without flow alignment can be manufactured with high efficiency by optimizing and setting the liquid crystal injection direction so that flow alignment does not occur.

It is possible to add the following structural features to the methods

for manufacturing a liquid crystal display panel as described in (4), (5) and (6), corresponding to the previous first to third embodiments.

In these configurations, the alignment processing step can include a rubbing process.

With this method, the first and second alignment films can be provided with a large alignment–regulating force by rubbing the alignment films, and it becomes possible to manufacture a liquid crystal display panel in which flow alignment is suppressed even better.

In these configurations, photosensitive alignment films can be used as the first alignment film and the second alignment film, and the alignment processing step can include a photoalignment process in which alignment processing is performed by irradiating light that is polarized in a predetermined direction.

Usually, when subjecting a photoalignment film to a photoalignment process, the alignment–regulating force of the alignment films is small, but also in this case, the occurrence of flow alignment is suppressed, and a liquid crystal display panel that is aligned uniformly in a predetermined direction is attained by optimizing the relation between the liquid crystal injection direction and the first and second alignment processing directions.

Second Aspect of the Invention

In order to solve the afore–mentioned conventional problems, the inventors of the present invention investigated liquid crystal display panels and methods for manufacturing the same. As a result, the inventors found

that it is possible to eliminate flow alignment caused by three–dimensional obstacles by injecting the liquid crystal from a direction in which the flow resistance of structural elements that may pose a flow resistance to the liquid crystal flow is suppressed to a minimum when injecting the liquid crystal.

(1) In order to attain the object of the present invention, a liquid crystal display panel having a liquid crystal cell is characterized in that the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port into the empty cell; and the liquid crystal injection port is arranged such that a liquid crystal injection direction substantially matches a direction for which, in a projection plane obtained by projecting structural elements inside the liquid crystal layer except for supporting members for holding a predetermined spacing between the pair of substrates in a direction parallel to the substrate plane onto a projection plane, the area of the region taken up by an empty portion, which is obtained by subtracting the projection area of the structural elements from the total projection area, becomes largest.

With this configuration, the direction for which, in a projection plane obtained by projecting structural elements constituting the liquid crystal cell in a direction parallel to the substrate plane onto a projection plane, the area of the region taken up by an empty portion, which is obtained by subtracting the projection area of the structural elements from the total

projection area, becomes largest is the direction in which the liquid crystal encounters the smallest flow resistance when flowing into the empty cell, and for which the flow path can be ensured best. Consequently, when in the liquid crystal display panel the liquid crystal injection port is arranged so that this direction substantially matches with liquid crystal injection direction, then the occurrence of flow alignment and of disclinations can be suppressed, and a liquid crystal display panel with excellent display quality can be obtained.

Furthermore, in this configuration, an alignment film can be provided on an inner side of each of the two substrates, and the alignment processing direction of the alignment films substantially can match the liquid crystal injection direction and the direction for which the area of the region taken up by the empty portion becomes largest.

(2) In order to attain the object of the present invention, a liquid crystal display panel having a liquid crystal cell is characterized in that the liquid includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port into the empty cell; and, when there are a plurality of directions for which, in a projection plane obtained by projecting structural elements inside the liquid crystal layer except for supporting members for holding a predetermined spacing between the pair of substrates in a direction parallel to the substrate plane onto a projection plane, the area of the region taken up by an empty portion, which is

obtained by subtracting the projection area of the structural elements from the total projection area, becomes largest, then the liquid crystal injection port is arranged such that the liquid crystal injection direction substantially matches a direction at which a flow path of the liquid crystal is ensured best.

In this configuration, when there are a plurality of directions for which the area of the region taken up by an empty portion, which is obtained by subtracting the projection area of the structural elements from the total projection area, becomes largest, then the liquid crystal is injected in the direction in which the flow path of the liquid crystal can be ensured best, whereby the influence of the flow resistance can be suppressed to a minimum. Consequently, by arranging the liquid crystal injection port in the liquid crystal display panel in this configuration so that the liquid crystal injection direction substantially matches with the direction for which the flow path of the liquid crystal can be ensured best, the occurrence of flow alignment and of disclinations can be suppressed, and a liquid crystal display panel with excellent display quality can be obtained.

(3) In order to attain the object of the present invention, a liquid crystal display panel having a liquid crystal cell is characterized in that the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port; the liquid crystal display panel modulates light passing through the liquid crystal cell with a transversal electric field

component applied in parallel to the substrate to display images; an electrode pair is provided on one substrate of the pair of substrates; and the liquid crystal injection port is arranged such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of the electrodes.

In this configuration, by matching the extension direction of the electrodes with the liquid crystal injection direction, it is possible to suppress the influence of the electrodes acting as a flow resistance on the flow of the liquid crystal. As a result, it is possible to reduce the occurrence of flow alignment and of disclinations.

(4) In order to attain the object of the present invention, a liquid crystal display panel having a liquid crystal cell is characterized in that the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port; the liquid crystal display panel modulates light passing through the liquid crystal cell with a transversal electric field component applied in parallel to the substrate to display images; an electrode pair is provided on one substrate of the pair of substrates; a color filter is arranged on the inside of the other substrate, the color filter being provided with a color pattern of red, green and blue and a light-blocking film arranged between the colors; and the liquid crystal injection port is arranged such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of a thickest

portion of the light–blocking film.

In this configuration, it is the light–blocking film, which poses the biggest flow resistance on the flow of the liquid crystal, that may become the cause for the occurrence of flow alignment. By substantially matching the extension direction of the thickest portions of this light–blocking film with the liquid crystal injection direction, the influence of the light–blocking film posing a flow resistance can be reduced to a minimum, and as a result, the occurrence of flow alignment can be reduced.

In the liquid crystal display panels according to (3) and (4), an alignment film can be provided on an inner side of each of the two substrates, and the alignment processing direction of these alignment films can substantially match the extension direction of the electrodes and the liquid crystal injection direction. The liquid crystal molecules flow with their long axis matching the flow direction, so that when the alignment processing direction of the alignment films is matched with the liquid crystal injection direction, the alignment–regulating force of the alignment films can regulate the liquid crystal more easily. As a result, it is possible to attain the desired initial alignment after the injection of the liquid crystal, and to suppress the occurrence of flow alignment even better.

In the liquid crystal display panels described in (3) and (4), the alignment films can be alignment processed by rubbing.

Furthermore, the alignment films can be made of polyimide–based resin.

Also, in the liquid crystal display panels described in (3) and (4), the

alignment films can be alignment processed by photoalignment.

Also the alignment films can be made of monomolecular adsorption films or polymer adsorption films in which clusters of film molecules constituting the alignment films are bonded / fixed to a surface of the substrates.

Also, in the liquid crystal display panels described in (3) and (4), the electrodes can be provided with a plurality of bending points, arranged such that while the electrodes are bent at each of the bending points in alternating directions, they extend overall in a predetermined direction.

Also, in the liquid crystal display panels described in (3) and (4), the electrode pair can be a pair of stripe–shaped parallel electrodes.

Also, in the liquid crystal display panels described in (3) and (4), the electrode pair can include two hook–shaped electrode portions having a long side and short sides defining a certain angle, with two ends of the hook–shaped electrode portions pointing in different directions.

(5) In order to attain the object of the present invention, a method for manufacturing a liquid crystal display panel having a liquid crystal cell, wherein the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates, and wherein the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port, includes a sealing member formation step of forming on one of the two substrates a frame–shaped sealing member having at least one open portion serving as a liquid crystal injection port; an aligning step of providing supporting

members on one of the two substrates, and aligning the pair of substrates together at a predetermined spacing, forming an empty cell; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal cell; wherein in the sealing member formation step, the sealing member is formed such that the liquid crystal injection direction when injecting the liquid crystal substantially matches a direction in which a flow resistance due to structural elements posing an obstacle for liquid crystal flow that are inside the liquid crystal layer, except the supporting members for holding a predetermined spacing between the pair of substrates, becomes minimal.

In the sealing member formation step, the sealing member formed on the substrate adheres the substrate pair together to produce an empty cell. When the sealing member is formed, it is necessary to consider position at which the liquid crystal injection port necessary for the liquid crystal injection is formed and its aperture direction.

Here, flow alignment occurs when the influence of the structural elements posing an obstacle on the liquid crystal flow, that is, a flow resistance, is large when injecting the liquid crystal into the empty cell. Thus, when the direction in which the liquid crystal flows is substantially matched with the direction in which the influence of the flow resistance is smallest, the occurrence of flow alignment can be decreased. Therefore, in the sealing member formation step, a portion of the sealing member is left open to form the liquid crystal injection port such that the liquid crystal injection direction matches with the direction in which the influence of the

flow resistance is smallest. Consequently, with this method, the occurrence of flow alignment is reduced, and it is possible to produce a liquid crystal display panel with excellent display quality, such as high contrast.

(6) In order to attain the object of the present invention, a method for manufacturing a liquid crystal display panel having a liquid crystal cell, wherein the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; and wherein the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port; includes an electrode formation step of forming a pair of electrodes on one of the two substrates; a sealing member formation step of forming on one of the two substrates a frame–shaped sealing member having at least one open portion serving as a liquid crystal injection port; an aligning step of providing supporting members on one of the two substrates, and aligning the pair of substrates together at a predetermined spacing, forming an empty cell; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal cell; wherein in the sealing member formation step, the sealing member is formed such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of the electrodes.

The electrodes are structural elements posing an obstacle to the liquid crystal flow, and consequently, the occurrence of flow alignment can be reduced by letting the liquid crystal flow in the liquid crystal injection step in the direction in which the flow resistance of the electrodes becomes

minimal. Consequently, with the method, by providing the sealing member with a liquid crystal injection port such that the liquid crystal injection direction substantially matches with the extension direction of the electrodes, the occurrence of flow alignment is reduced, and it is possible to manufacture a liquid crystal display panel with excellent display quality, such as high contrast.

The afore–mentioned method can further include an alignment film formation step of forming alignment films on the two substrates; and an alignment processing step of alignment processing the alignment films; wherein in the sealing member formation step, the sealing member is provided with the liquid crystal injection port such that the alignment processing direction in the alignment processing step substantially matches the liquid crystal injection direction.

(7) In order to attain the object of the present invention, a method for manufacturing a liquid crystal display panel having a liquid crystal cell, wherein the liquid crystal cell includes at least one liquid crystal injection port provided on a rim of an empty cell made by disposing a sealing member between a pair of substrates; and wherein the liquid crystal cell is made by injecting liquid crystal through the liquid crystal injection port; includes a color filter formation step of forming on one of the two substrates a color filter including a color pattern of R (red), G (green) and B (blue) and a light–blocking film separating these colors; a sealing member formation step of forming on one of the two substrates a frame–shaped sealing member having at least one open portion serving as a liquid crystal injection port; an

aligning step of providing supporting members on one of the two substrates, and aligning the pair of substrates together at a predetermined spacing, forming an empty cell; and a liquid crystal injection step of injecting liquid crystal material through the liquid crystal injection port to form a liquid crystal cell; wherein in the sealing member formation step, the sealing member is formed such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of a highest portion of the light–blocking film.

The light–blocking film of the color filter and the electrodes both are structural elements that pose an obstacle to the liquid crystal flow, but comparing the two, it is the light–blocking film that poses the bigger flow resistance. Consequently, with this method, it is possible to manufacture a liquid crystal display panel with excellent display quality, such as high contrast .by providing the sealing member with a liquid crystal injection port such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of a highest portion of the light–blocking film.

This method can further include an alignment film formation step of forming alignment films on the two substrates; and an alignment processing step of alignment processing the alignment films; wherein in the sealing member formation step, the liquid crystal injection port is formed such that the liquid crystal injection direction substantially matches the alignment processing direction in the alignment processing step.

This method can further include an electrode formation step of

forming a pair of electrodes on one of the two substrates, wherein in the sealing member formation step, the sealing member is provided with the liquid crystal injection port such that the liquid crystal injection direction substantially matches an extension direction of the electrodes.

This method can further include an alignment film formation step of forming alignment films on the two substrates; and an alignment processing step of alignment processing the alignment films; wherein in the sealing member formation step, the sealing member is provided with the liquid crystal injection port such that the liquid crystal injection direction substantially matches the extension direction of the electrodes and the alignment processing direction in the alignment processing step.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view schematically showing the relation between the alignment processing direction for the alignment films and the liquid crystal injection direction in a liquid crystal display panel with homogenous alignment according to an embodiment of the first aspect of the present invention.

Fig. 2 is a plan view diagrammatically showing the flow direction when injecting liquid crystal into an empty cell in this liquid crystal display panel.

Fig. 3 is a perspective view schematically showing the relation between the alignment process directions of the alignment films and the liquid crystal injection direction for a liquid crystal display panel with TN

alignment structure according to an embodiment of the first aspect of the present invention.

Fig. 4 is a diagram showing how the effect of the alignment–regulating force of the alignment films realigns the alignment processing direction of the liquid crystal that is injected into an empty cell in the alignment processing direction in a liquid crystal display panel according to an embodiment of the first aspect of the present invention.

Fig. 5 illustrates diagrammatically a liquid crystal cell according to an embodiment of the first aspect of the present invention. Fig. 5(a) is a plan view diagrammatically showing the liquid crystal cell. Fig. 5(b) is a cross–sectional view of the liquid crystal cell in Fig. 5(a), taken in arrow direction along the line X – X'.

Fig. 6 illustrates the relation between the liquid crystal injection direction and the alignment processing direction of the alignment films for the homogeneous alignment mode in this liquid crystal cell.

Fig. 7 is a perspective view illustrating diagrammatically the photoalignment method in the alignment films of this liquid crystal cell.

Fig. 8 illustrates the relation between the liquid crystal injection direction and the alignment processing direction for the TN alignment mode in this liquid crystal cell.

Fig. 9 is a diagrammatical cross–sectional view of an IPS mode liquid crystal display panel according to a second aspect of the present invention.

Fig. 10 is a schematic plan view of a pair of electrodes, including a

pixel electrode and an opposing electrode, in this liquid crystal display panel.

Fig. 11 is a projection drawing of the structural elements constituting the liquid crystal display panel. Fig. 11(a) is a projection drawing, projected in a direction parallel to the extension direction of the pixel electrode portions and opposing electrodes portions. Fig. 11(b) is a projection drawing , projected in a direction perpendicular to the extension direction of the pixel electrode portions and opposing electrodes portions.

Fig. 12 is a plan view schematically illustrating the extension direction of the electrodes and the liquid crystal injection direction when injecting the liquid crystal into the empty cell of the liquid crystal display panel.

Fig. 13 is a diagrammatical cross–sectional view of an IPS mode liquid crystal display panel with a color filter according to an embodiment of the second aspect of the present invention.

Fig. 14 illustrates the color filter of the liquid crystal display panel. Fig. 14(a) is a partial plan view showing the R (red), G (green) and B (blue) color pattern of the color filter, Fig. 14(b) is a cross–sectional view taken in arrow direction along the line a – a' in Fig. 14(a), and Fig. 14(c) is a cross–sectional view taken in arrow direction along the line b – b' in Fig. 14(a).

Fig. 15 is a projection drawing of the structural elements constituting the liquid crystal display panel. Fig. 15(a) is a projection drawing, projected in a direction parallel to the extension direction of the

longer portions of the black matrix. Fig. 15(b) is a projection drawing, projected in a direction parallel to the extension direction of the shorter portions of the black matrix.

Fig. 16 is a plan view schematically illustrating the extension direction of the longer portions of the black matrix and the liquid crystal injection direction when injecting the liquid crystal into the empty cell of the liquid crystal display panel.

Fig. 17 illustrates a case when there are a plurality of directions in which the area of the region taken up by the empty portions of the empty cell projected onto the projection plane is largest. Fig. 17(a) is a plan view diagrammatically showing the structural elements posing a flow resistance. Fig. 17(b) is a projection drawing of the empty cell taken from the X direction. Fig. 17(b) is a projection drawing of the empty cell taken from the Y direction.

Fig. 18 is a plan view diagrammatically showing another pair of electrodes according to the second aspect of the present invention. Fig. 18(a) shows a pair of stripe–shaped parallel electrodes. Fig. 18(b) shows a pair of electrodes having long sides and short sides.

Fig. 19 is a plan view schematically showing the planar shape of the electrodes provided on the electrode substrate in Working Example 2–1 according to the second aspect of the present invention.

Fig. 20 illustrates how the adsorption molecules are chemically adsorbed to the substrate surface. Fig. 20(a) illustrates the situation before the reaction of the adsorption molecules with the water content. Fig. 20(b)

illustrates the situation immediately after the reaction of the adsorption molecules with the water content.

BEST MODE FOR CARRYING OUT THE INVENTION

(1) Embodiment According to the First Aspect of the Invention

The following explains the first aspect of the present invention, with reference to the accompanying drawings.

An embodiment of the present invention is explained with reference to Figs. 1 to 3. It should be noted, however, that these drawings show only portions relating to the present invention, whereas other structural elements have been omitted. For illustrative reasons, some portions are shown magnified or shrunk.

The technical idea behind the present invention is to optimize the injection direction, when injecting the liquid crystal in view of the alignment processing direction of the alignment film, so as to eliminate or suppress the occurrence of flow alignment.

The following is an explanation of specific embodiments for optimization of the liquid crystal injection direction for a case where the liquid crystal has a parallel alignment structure, and for a case where the liquid crystal has a twisted alignment structure.

First, a liquid crystal display panel is explained, in which a liquid crystal layer in parallel alignment is provided between a pair of substrates arranged in opposition and each provided with an alignment film. In this case, the injection direction of the liquid crystal is set to be approximately parallel to the alignment processing direction, which is parallel for the two alignment films.

Fig. 1 is a perspective view schematically showing the relation between the alignment processing direction for the alignment films and the liquid crystal injection direction in a liquid crystal cell with parallel alignment (homogenous alignment). Fig. 2 is a plan view diagrammatically showing the flow direction when injecting liquid crystal into an empty cell. As shown in Fig. 1, an alignment film 1 (first alignment film) and an alignment film 2 (second alignment film) arranged at top and bottom are alignment processed in the direction indicated by arrow A in Fig. 1 (first and second alignment processing direction). When the liquid crystal is injected from a liquid crystal injection port 5 into the empty cell with alignment films 1 and 2 that have been alignment processed like this, the flow direction of the liquid crystal widens up isotropically from the liquid crystal injection port 5, as shown in Fig. 2(a). When eventually some of the liquid crystal has reached the two lateral edges, the overall flow direction of the liquid crystal becomes the same as the liquid crystal injection direction (see Fig. 2(b)).

If the liquid crystal flows into a certain direction, the long axis of the liquid crystal molecules is arranged to be parallel to the flow direction. If directly after the injection, the alignment direction of the liquid crystal molecules differs somewhat from the alignment processing direction, then the effect of the alignment–regulating force of the alignment films 1 and 2 attempts to align the liquid crystal in the alignment processing direction. On the other hand, since the liquid crystal behaves as molecule clusters, it attempts to uphold its flow alignment state. That is to say, the

determining factor governing the flow alignment in liquid crystal display panels seems to be the question whether the energy arising from the collective behavior of the liquid crystal, which attempts to sustain the flow alignment state, is greater or smaller than the alignment–regulating force of the alignment film.

However, in the present invention, by making direction A and/or direction A', which are approximately parallel with the alignment processing direction, the flow direction of the liquid crystal, as shown in Fig. 1, the necessity to realign the liquid crystal from the liquid crystal injection direction to the alignment processing direction is eliminated. That is to say, by letting the flow alignment coincide with the alignment processing direction, one fundamental factor in the occurrence of flow alignment, namely the discrepancy between the liquid crystal injection direction and the alignment processing direction is done away with, thus taking away the possibility for flow alignment.

If the liquid crystal is in parallel alignment as described in the foregoing, the liquid crystal injection ports for injecting the liquid crystal has to be arranged in the direction A and A' on the sides of the rectangular substrate. Also, the aperture direction has to be approximately parallel to the alignment processing direction.

The following describes a liquid crystal display panel having a twisted structure (for example, TN or STN alignment mode), in which the alignment processing direction of the upper and the lower alignment films are rotated for a finite angle against one another. In that case, flow

alignment can be eliminated or its occurrence can be suppressed by injecting the liquid crystal from one of the two injection directions described below.

As a first injection method, the injection direction of the liquid crystal is set to be parallel to the direction that divides the intersection angle defined by the alignment processing direction in one alignment film and the alignment processing direction in the other alignment film into two equal angles or substantially equal angles.

The following explains an example of a TN liquid crystal, in which the long axis of the liquid crystal molecules is continually twisted for 90° between the upper and the lower substrate. Fig. 3 is a perspective view schematically showing the relation between the alignment process directions of the alignment films and the liquid crystal injection direction for a TN liquid crystal having a twisted structure with a 90° twist angle. Fig. 4 is a diagram showing how the effect of the alignment–regulating force of the alignment films 1 and 2 realigns the liquid crystal that is injected into an empty cell in the alignment processing direction.

As shown in Figs. 3 and 4(a), the alignment processing direction in the alignment film 1 is parallel to the direction of the arrow A (first alignment processing direction). On the other hand, the alignment processing direction in the alignment film 2 is parallel to the direction of the arrow B (second alignment processing direction). The intersection angle between the alignment processing directions A and B is represented by θ (=90°). In a TN liquid crystal cell with this configuration, the liquid crystal is injected by the first injection method from the direction of the arrow C or

the arrow C'. For example, if the liquid crystal is injected from the direction of the arrow C as shown in Fig. 4(a), the alignment–regulating force of the alignment film 1 rotates the liquid crystal molecules 11 near the alignment film 1 by the angle ϕLC_1 in the plane parallel to the substrate, aligning the liquid crystal molecules 11 in the direction of the arrow A. On the other hand, the liquid crystal molecules 12 near the alignment film 2 are rotated by the alignment film 2 for the angle ϕLC_2, aligning them in the direction of the arrow B. Furthermore, the liquid crystal molecules in the middle of the liquid crystal layer are already arranged in the alignment processing direction when they are injected, so that this alignment state hardly changes. To be more precise, the angles ϕLC_1 and ϕLC_2 change within the ranges $0° \leqq \phi LC_1 \leqq 45°$ and $-45° \leqq \phi LC_2 \leqq 0°$ in planes parallel to the substrates.

As mentioned above, the occurrence of flow alignment is determined by the question whether the energy arising from the collective behavior of the liquid crystal, which attempts to sustain the flow alignment state, is greater or smaller than the alignment–regulating force of the alignment film. Consequently, to align the liquid crystal in the desired direction without causing flow alignment, a certain minimum alignment–regulating force is necessary. Due to these considerations, the direction that divides the intersection angle between the alignment processing directions of the alignment films 1 and 2 into two equal angles is set to be parallel to the injection direction of the liquid crystal. That is to say, by making the discrepancy between the liquid crystal injection direction and the alignment

processing direction small, the liquid crystal injection direction is optimized so that its energy is greater than the energy with which the alignment–regulating force attempts to sustain the flow alignment. Moreover, since the liquid crystal is in twisted alignment, the alignment films 1 and 2 considerably change the alignment direction only in a small portion of the liquid crystal molecules. Also, the alignment direction of a portion of the liquid crystal molecules coincides with the injection direction, so that these liquid crystal molecules remain in their initial orientation. Thus, even with alignment films with small alignment–regulating force, it is possible to align the liquid crystal sufficiently in the desired direction, and to eliminate or suppress the occurrence of flow alignment.

As a second injection method, the injection direction of the liquid crystal is set to be perpendicular to the direction that divides the intersection angle defined by the alignment processing direction in one alignment film and the alignment processing direction in the other alignment film into two equal angles or into two substantially equal angles.

When the arrangement of the liquid crystal is that of TN liquid crystal mode, the liquid crystal can be injected in the direction of the arrow D or the arrow D', as shown in Fig. 3. More specifically, if the liquid crystal is inserted for example in the direction of the arrow D, then the liquid crystal molecules 11 near the alignment film 1 are regulated by the alignment–regulating force of the alignment layer 1, and rotated by the angle ϕLC_3 ($\fallingdotseq 45°$), aligning the liquid crystal molecules 11 in the direction of the arrow A, as shown in Fig. 4(b). On the other hand, the liquid crystal

molecules 12 near the alignment film 2 are rotated by the alignment film 2 for the angle ϕLC_4 ($\fallingdotseq -45°$), aligning the liquid crystal molecules 12 in the direction of the arrow B.

Thus, since the liquid crystal injection direction is perpendicular with respect to the direction that divides the intersection angle into two equal angles, the liquid crystal molecules 11 and 12 near the alignment films 1 and 2 can be aligned adequately in the desired direction, due to the alignment–regulating force in the alignment films 1 and 2. Consequently, a liquid crystal display panel can be attained, in which the occurrence of flow alignment can be eliminated or suppressed.

The foregoing explanations related to examples of the TN alignment mode, but flow alignment can also be suppressed with the same principles in the STN alignment mode. That is to say, by injecting the liquid crystal in substantially the same direction as for TN liquid crystal mode, the occurrence of flow alignment can be suppressed, and variations in the injection speed can be eliminated. Furthermore, as mentioned above, if the liquid crystal is arranged in twisted alignment, the aperture direction of the liquid crystal injection port for the injection of liquid crystal should be formed to be approximately parallel or perpendicular to the direction dividing the intersection angle between the alignment processing directions of the alignment films 1 and 2 into two equal angles. In the case of STN alignment mode with a twisting angle of 180°, the liquid crystal injection direction should be parallel to a direction that forms a perpendicular angle with the alignment processing direction. In that case, the liquid crystal

molecules near the alignment film try to align themselves with the alignment processing directions by rotating for 90° each. Another case that seems to be conceivable is to make the alignment processing direction parallel to the liquid crystal injection direction. In that case, due to the matching of the alignment processing direction of one alignment film with the liquid crystal injection direction, the alignment of the liquid crystal molecules near one alignment film does not change, so that at first sight this would seem to be advantageous. However, the directionality of the other alignment processing direction is completely opposite to that of the liquid crystal injection direction, and the liquid crystal molecules have their own directionality, so that the liquid crystal molecules near that other alignment film have to be aligned by a rotation of 180°. Therefore, flow alignment remains.

There is no particular limitation with regard to the alignment films 1 and 2 of the present invention, and various alignment film as known in the art can be used. More specifically, examples of suitable alignment films are silane–based films and polyimide–based resin films, which are alignment films made of film molecules including straight carbon chains that are directly or indirectly chemisorptive on a substrate via siloxane bonds (Si–O–) at one end of the straight carbon chains. Since silane–based films are thin, they are susceptible to the influence of flow alignment, for example the alignment direction of the film molecules may change due to flow alignment. Furthermore, their alignment–regulating force is smaller than that of polyimide–based resin films for example, so that flow alignment

tends to occur more easily. The influence of flow alignment is particularly conspicuous when it is formed as a monomolecular film. However, in the present invention, it is possible to suppress the influence of flow alignment to a minimum, because the liquid crystal is injected from a direction that is optimized as described above, in consideration of the relation between the liquid crystal injection direction and the alignment processing direction of the alignment films. Also for polyimide–based resin films, in the case of photosensitive alignment films with photosensitive groups, in particular cinnamate groups, chalcone groups etc., in a portion of the main chains or side chains of the film molecules, those photosensitive groups are easily susceptible to the influence of the liquid crystal flow, so that they may be aligned in the flow direction of the liquid crystal, and the surface structure of the photosensitive alignment films may be physically changed. But also in this case, the present invention can suppress the influence of the flow alignment to a minimum. Also when photosensitive groups are included in the film molecules constituting the silane–based film, the influence of flow alignment can be eliminated as described above.

Thus, with the present invention, it is possible to eliminate or suppress the occurrence of flow alignment by optimizing the alignment processing direction of the alignment films and the injection direction when injecting the liquid crystal, but when a heating process at a predetermined temperature is performed during the injection or after the injection of the liquid crystal material, an alignment structure can be attained, in which the liquid crystal is aligned even more uniformly in the desired direction. That

is to say, heating the liquid crystal above the N–I phase transition temperature, the thermal equilibrium of the liquid crystal makes a phase change from the nematic phase to the isotropic phase (isotropic fluid). As a result, it is possible to eliminate any flow alignment that has remained in slight amounts by turning the liquid crystal from an disordered into an isotropic fluid.

Furthermore, it is possible to provide one liquid crystal injection port or a plurality of liquid crystal injection ports.

Working Examples

Referring to the accompanying drawings, the following is a more detailed explanations of preferable working examples of the invention. However, it should be understood that, if not noted otherwise, the dimensions, material, shapes, relative arrangement etc. of the structural elements described in these working examples are not limiting upon the scope of the present invention, and are merely illustrative examples.

First, the basic structure of a liquid crystal cell used in this working example is described with reference to Fig. 5. Fig. 5(a) is a plan view schematically showing a liquid crystal cell used in this working example. Fig. 5(b) is a cross–sectional view of this liquid crystal cell, taken in arrow direction along the line X – X'. In these drawings, the liquid crystal cell includes a first substrate 3, a second substrate 4 opposing the first substrate 3, and a liquid crystal layer 9 arranged between these substrates. On the inner surface of the first substrate 3, a circular electrode 6 is formed as a

display electrode, and an alignment film 1 is formed on the circular electrode 6. On the other hand, a circular electrode 7 is formed as a display electrode on the inner surface of the second substrate 4, and an alignment film 2 is formed on the circular electrode 7. A frame–shaped sealing member 8 for aligning the first substrate 3 and the second substrate 4 together is formed, leaving a portion serving as a liquid crystal injection port 5 at the rim of the liquid crystal cell open.

Below, liquid crystal cells with this configuration are described for two liquid crystal alignment modes, namely the homogeneous alignment mode and the TN alignment mode.

Homogeneous Alignment Mode

If the liquid crystal is aligned in the homogeneous alignment mode, the alignment processing directions of the alignment films 1 and 2 are parallel. Here, the liquid crystal cells with homogeneous alignment mode are classified into the five types H–1 to H–5, depending on the relation between the alignment processing directions of the alignment films 1 and 2 and the liquid crystal injection direction. Fig. 6 illustrates the angle α between the liquid crystal injection direction and the alignment processing direction for these alignment types. For each alignment type shown in Fig. 6, the liquid crystal cell was manufactured, taking the alignment film material and the alignment processing direction as parameters, and it was examined, how the relation between the liquid crystal injection direction and the alignment processing direction influences the occurrence of flow

alignment, as discussed in the following Working Examples 1–1 to 1–4 and Comparative Examples 1–1 to 1–16. Table 1–1 lists the various alignment types, and the combination of alignment film material and alignment method used.

Table 1–1

alignment type	polyimide alignment film		silane–based alignment film	
	rubbing	photoalignment	rubbing	photoalignment
H–1	liquid crystal cell A1	liquid crystal cell A2	liquid crystal cell A3	liquid crystal cell A4
H–2	comparative liquid crystal cell B1	comparative liquid crystal cell B5	comparative liquid crystal cell B9	comparative liquid crystal cell B13
H–3	comparative liquid crystal cell B2	comparative liquid crystal cell B6	comparative liquid crystal cell B10	comparative liquid crystal cell B14
H–4	comparative liquid crystal cell B3	comparative liquid crystal cell B7	comparative liquid crystal cell B11	comparative liquid crystal cell B15
H–5	comparative liquid crystal cell B4	comparative liquid crystal cell B8	comparative liquid crystal cell B12	comparative liquid crystal cell B16

Working Example 1–1

The liquid crystal cell according to Working Example 1–1 uses an alignment film made of a polyimide resin, which is rubbed to the alignment type H–1 shown in Table 1–1.

The liquid crystal cell was made by the method explained in the following. First, a circular electrode 7 was formed on the second substrate 4 by one of the methods known in the art. Then, polyimide was dissolved and diluted in a solvent such as N–methyl pyrrolidinone to prepare a

coating solution. This coating solution was applied on the second substrate 4 and the circular electrode 7 by a spinner or the like, and dried / burned, forming an alignment film 2 (polyimide alignment film) of 50nm thickness.

The alignment film 2 formed in this manner was aligned by rubbing. To be more specific, the second substrate 4 was placed on a stage, and a cylindrical roller provided with corrugations around which a cloth has been wound was placed on the alignment film 2, and the stage was shifted in one direction while rotating the roller. Thus, convex and concave stripes that are parallel to the shifting direction of the roller were formed on the surface of the alignment film 2, and the polyimide molecules at the surface of the alignment film 2 were tilted in the shifting direction of the roller. As the rubbing parameters for this process, the rubbing was performed once, the roller indentation was 0.4mm, the rubbing speed of the roller surface with respect to the second substrate 4 was 500m/min, and a nylon cloth (with 16 to 20μm fiber diameter and 3nm fiber length) was used.

The same process was also performed with the first substrate 3, thus forming a circular electrode 6 and an alignment film 1 on the first substrate 3, and aligning the alignment film 1 by rubbing.

Then, a sealing member 8 was applied on either the first substrate 3 or the second substrate 4 in a frame–shaped pattern, leaving the portion serving as a liquid crystal injection port 5 open. The liquid crystal injection port 5 was arranged such that it was open in a direction parallel to the alignment processing direction.

Then, the first substrate 3 and the second substrate 4 were aligned

together, such that the alignment film 1 on the first substrate 3 was placed in opposition to the alignment film 2 on the second substrate 4, thus forming an empty cell. Then, a nematic liquid crystal with positive dielectric anisotropy was filled into the empty cell from the liquid crystal injection port 5 by vacuum injection, thus forming a liquid crystal layer 9. As the injection parameters for the vacuum injection, the exhaust speed when exhausting air from the empty cell was set from 760Torr to 2.0×10^{-1}Torr for 15min, then held at 2.0×10^{-1}Torr for 15min, and then the vacuum degree was set to 6.0×10^{-3}Torr, and the leak time during the liquid crystal injection was set to 15min (at 760Torr). The liquid crystal cell according to Working Example 1–1 prepared in this manner is referred to as liquid crystal cell A1 in the following.

<u>Comparative Example 1–1 to Comparative Example 1–4</u>

The comparative liquid crystal cells of Comparative Examples 1–1 to 1–4 differ from the configuration of the liquid crystal cell in Working Example 1–1 in that the alignment type has been changed from H–1 to H–2 through H–5.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–1. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 formed a predetermined angle α with the alignment processing

direction.

The liquid crystal cells of Comparative Examples 1–1 to 1–4 prepared in this manner are referred to as the comparative liquid crystal cells B1 to B4 in the following.

Working Example 1–2

The liquid crystal cell according to Working Example 1–2 differs from the configuration of the liquid crystal cell in Working Example 1–1 in that a polyimide resin film including photopolymerizing chalcone groups instead of the polyimide resin is used, and its manufacturing method is different in that it uses a photoalignment process for the alignment process.

A liquid crystal cell according to Working Example 1–2 was prepared with the same method as in Working Example 1–1. However, the alignment film was aligned not by a rubbing process, but by a photoalignment process as explained below. That is to say, as shown in Fig. 7, UV light (with a wavelength of 365nm), polarized in the direction indicated by the arrow T, was irradiated on the alignment film 1 for 6sec at an irradiation intensity of 80mW/cm^2 from the direction indicated by the arrow S at an angle δ = 45° with respect to the second substrate 4. This polymerizes and crosslinks the chalcone groups in a direction parallel to the polarization direction, and the polyimide molecules themselves tilt to the side opposite from the irradiation side with respect to the irradiation point R of the polarized UV light in the alignment film 1. Thus, the alignment film 1 is alignment processed in a direction corresponding to the

polarization direction projected onto the alignment film 1 on the side opposite the irradiation side. Moreover, also the alignment film 2 was alignment processed into the same alignment processing direction by performing the same step.

The liquid crystal cell according to Working Example 1–2 prepared in this manner is referred to as liquid crystal cell A2 in the following.

<u>Comparative Example 1–5 to Comparative Example 1–8</u>

The comparative liquid crystal cells of Comparative Examples 1–5 to 1–8 differ from the configuration of the liquid crystal cell in Working Example 1–2 in that the alignment type has been changed from H–1 to H–2 through H–5.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–2. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 formed a predetermined angle α with the alignment processing direction.

The liquid crystal cells of Comparative Examples 1–5 to 1–8 prepared in this manner are referred to as the comparative liquid crystal cells B5 to B8 in the following.

Working Example 1–3

The liquid crystal cell according to Working Example 1–3 differs from the configuration of the liquid crystal cell in Working Example 1–1 in that a silane–based film is used instead of the polyimide resin.

The alignment film according to Working Example 1–3 was formed in the following manner. A silane–based surfactant including molecules with n–$C_{10}H_{21}$ groups was dissolved to a concentration of 0.2wt% in a non–aqueous organic solvent made of thoroughly dehydrated chloroform, thus producing a chemical adsorption solution.

Then, the second substrate 4 was immersed for about one hour in the chemical adsorption solution, and the molecules with the n–$C_{10}H_{21}$ groups were chemically adsorbed on the circular electrode 7, forming a monomolecular film. Since the surface of the second substrate 4 and the circular electrode 7 is hydrophilic and includes functional groups with active hydrogen, such as –OH groups, the functional groups with Si and the –OH groups undergo a dehydrochlorination reaction, forming siloxane bonds.

Then, the second substrate 4 was retrieved from the chemical adsorption solution and rinsed for about 10min with a cleaning agent made of thoroughly dehydrated chloroform, which is a non–aqueous solvent. Thus, the silane–based surfactant that had not yet reacted was eliminated.

Moreover, placing the second substrate 4 in a drying atmosphere and lifting one end of the second substrate 4, the cleaning agent was removed. Thus, the monomolecular film was tilted in the direction in which the cleaning agent was removed, which is opposite to the lifting direction.

After the second substrate 4 was dried, it was retrieved into a normal atmosphere, causing a reaction with the water content in the air. Thus, the not yet reacted Cl–groups in the molecules that are chemically adsorbed on the circular electrode 7 are substituted with OH–groups. Then, the OH–groups were dehydrated by drying the second substrate 4, and as a result, an alignment film with a film thickness of, for example, about 5nm could be formed. The alignment film formed in this manner was alignment processed by rubbing, as in Working Example 1–1.

The liquid crystal cell according to Working Example 1–3 prepared in this manner is referred to as liquid crystal cell A3 in the following.

Comparative Example 1–9 to Comparative Example 1–12

The comparative liquid crystal cells of Comparative Examples 1–9 to 1–12 differ from the configuration of the liquid crystal cell in Working Example 1–3 in that the alignment type has been changed from H–1 to H–2 through H–5.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–3. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 formed a predetermined angle α with the alignment processing direction.

The liquid crystal cells of Comparative Examples 1–9 to 1–12

prepared in this manner are referred to as the comparative liquid crystal cells B9 to B12 in the following.

Working Example 1–4

The liquid crystal cell according to Working Example 1–4 differs from the configuration of the liquid crystal cell in Working Example 1–3 in that a silane–based film with photopolymerizing chalcone groups is used instead of the silane–based film, and that a photoalignment process was performed as the alignment method.

The alignment film according to Working Example 1–4 was formed in the following manner. A silane–based surfactant including molecules with C_6H_5–CH–CO–C_6H_4–O–(CH_2)–O– groups including chalcone groups was dissolved to a concentration of 0.2wt% in a non–aqueous organic solvent made of thoroughly dehydrated chloroform, thus obtaining a chemical adsorption solution. Using this chemical adsorption solution, an alignment film was formed with the same method as in Working Example 1–3.

Then, the alignment film formed in this manner was subjected to a photoalignment process. That is to say, UV light polarized in the direction parallel to a lifting direction, was irradiated for 6sec at an irradiation intensity of 80mW/cm^2 from a direction perpendicular to the second substrate 4. This polymerized and crosslinked the chalcone groups in a direction parallel to the polarization direction. Thus, the alignment film 1 was alignment processed in a direction corresponding to the polarization direction projected onto the alignment film 1 on the side opposite the

irradiation side of the UV light.

Moreover, by performing the same step with the first substrate 3 as well, an alignment film 1 was formed on the circular electrode 6.

The liquid crystal cell according to Working Example 1–4 prepared in this manner is referred to as liquid crystal cell A4 in the following.

Comparative Example 1–13 to Comparative Example 1–16

The comparative liquid crystal cells of Comparative Examples 1–13 to 1–16 differ from the configuration of the liquid crystal cell in Working Example 1–4 in that the alignment type has been changed from H–1 to H–2 through H–5.

Moreover, the comparative liquid crystal cells were formed by basically the same steps as in Working Example 1–4. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 formed a predetermined angle α with the alignment processing direction.

The liquid crystal cells of Comparative Examples 1–13 to 1–16 prepared in this manner are referred to as the comparative liquid crystal cells B13 to B16 in the following.

Results

Making display screens with the liquid crystal cells according to

Working Examples 1–1 to 1–4 and Comparative Examples 1–1 to 1–13 made as described above and examining them through a polarizer with the bare eye and with a polarization microscope, the results listed in the following Table 1–2 were obtained.

Table 1–2

type of liquid crystal cell	occurrence of flow alignment	alignment condition
liquid crystal cell A1	N	mono–domain
liquid crystal cell A2	N	mono–domain
liquid crystal cell A3	N	mono–domain
liquid crystal cell A4	N	mono–domain
comp. liquid crystal cell B1	Y	mono–domain
comp. liquid crystal cell B2	Y	mono–domain
comp. liquid crystal cell B3	Y	mono–domain
comp. liquid crystal cell B4	Y	mono–domain
comp. liquid crystal cell B5	Y	mono–domain
comp. liquid crystal cell B6	Y	multi–domain
comp. liquid crystal cell B7	Y	mono–domain
comp. liquid crystal cell B8	Y	multi–domain
comp. liquid crystal cell B9	Y	mono–domain
comp. liquid crystal cell B10	Y	multi–domain
comp. liquid crystal cell B11	Y	mono–domain
comp. liquid crystal cell B12	Y	multi–domain
comp. liquid crystal cell B13	Y	mono–domain
comp. liquid crystal cell B14	Y	multi–domain
comp. liquid crystal cell B15	Y	mono–domain
comp. liquid crystal cell B16	Y	multi–domain

N: no occurrence of flow alignment Y: occurrence of flow alignment

As becomes clear from Table 1–2, it is possible to prevent the

occurrence of flow alignment by performing the alignment processing of the alignment films 1 and 2 and the liquid crystal injection in substantially parallel directions.

TN Alignment Mode

If the liquid crystal is arranged in the TN alignment mode, the alignment processing directions of the alignment film 1 and the alignment film 2 are rotated by a finite angle relative to one another. Here, the liquid crystal cells in TN alignment mode are classified into the types T–1 to T–5, depending on the relation between the alignment processing directions of the alignment films 1 and 2 and the liquid crystal injection direction. Fig. 8 illustrates the angle β defined by the liquid crystal injection direction and the alignment processing direction for these alignment types. For each of the alignment types shown in Fig. 8, a liquid crystal cell was produced, taking the alignment film material and the alignment method as parameters, and it was examined, what influence the relation between the liquid crystal injection direction and the alignment processing direction has on the occurrence of flow alignment, as discussed in the following Working Examples 1–5 to 1–10 and Comparative Examples 1–17 to 1–30. In the TN alignment mode examples explained below, the intersection angle between the alignment processing directions of the alignment film 1 and the alignment film 2 was set to 90°. Table 1–3 lists the alignment types and the corresponding alignment film materials and alignment methods.

Table 1–3

alignment type	polyimide alignment film		silane–based alignment film	
	rubbing	photoalignment	rubbing	photoalignment
T–1	liquid crystal cell A5	liquid crystal cell A8	liquid crystal cell A9	liquid crystal cell A10
T–2	comparative liquid crystal cell B17	comparative liquid crystal cell B19	comparative liquid crystal cell B23	comparative liquid crystal cell B27
T–3	liquid crystal cell A6	comparative liquid crystal cell B20	comparative liquid crystal cell B24	comparative liquid crystal cell B28
T–4	comparative liquid crystal cell B18	comparative liquid crystal cell B21	comparative liquid crystal cell B25	comparative liquid crystal cell B29
T–5	liquid crystal cell A7	comparative liquid crystal cell B22	comparative liquid crystal cell B26	comparative liquid crystal cell B30

Working Example 1–5

The liquid crystal cell of Working Example 1–5 differs from the configuration of the liquid crystal cell in Working Example 1–1 in that the alignment type has been changed from H–1 to T–1.

The liquid crystal cells was prepared with the same method as in Working Example 1–1. Needless to say, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 was arranged to be parallel to a line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles.

The liquid crystal cell of Working Example 1–6 prepared in this manner is referred to as the liquid crystal cell A5 in the following.

Comparative Example 1–17 and Comparative Example 1–18

The comparative liquid crystal cells of Comparative Examples 1–17 to 1–18 differ from the configuration of the liquid crystal cell in Working Example 1–1 in that the alignment type has been changed from T–1 to T–2 and T–4.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–1. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cells of Comparative Examples 1–17 and 1–18 prepared in this manner are referred to as the comparative liquid crystal cells B17 to B18 in the following.

Working Example 1–6 and Working Example 1–7

The liquid crystal cells of Working Example 1–6 and Working Example 1–7 differ from the configuration of the liquid crystal cell in Working Example 1–5 in that the alignment type has been changed from T–1 to T–3 and T–5.

The liquid crystal cells were prepared with basically the same steps

as in Working Example 1–1. Needless to say, in each of these working examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cells of Working Example 1–6 and Working Example 1–7 prepared in this manner are referred to as the liquid crystal cell A6 and liquid crystal cell A7 in the following.

Working Example 1–8

The liquid crystal cell of Working Example 1–8 differs from the configuration of the liquid crystal cell of Working Example 1–2 in that the alignment type has been changed from H–1 to T–1.

The liquid crystal cell was prepared with the same method as in Working Example 1–2. Needless to say, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 was arranged to be parallel to the alignment processing directions of the alignment film 1.

The liquid crystal cell of Working Example 1–8 prepared in this manner is referred to as the liquid crystal cell A8 in the following.

Comparative Example 1–19 to Comparative Example 1–22

The comparative liquid crystal cells of Comparative Examples 1–19 to 1–22 differ from the configuration of the liquid crystal cell in Working Example 1–9 in that the alignment type has been changed from T–1 to T–2 through T–5.

Moreover, the comparative liquid crystal cells were formed by basically the same steps as in Working Example 1–8. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cells of Comparative Examples 1–19 to 1–22 prepared in this manner are referred to as the comparative liquid crystal cells B19 to B22 in the following.

Working Example 1–9

The liquid crystal cell of Working Example 1–9 differs from the configuration of the liquid crystal cell of Working Example 1–3 in that the alignment type has been changed from H–1 to T–1.

The liquid crystal cell was prepared with basically the same method as in Working Example 1–3. Needless to say, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate

4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cell of Working Example 1–9 prepared in this manner is referred to as the liquid crystal cell A9 in the following.

Comparative Example 1–23 to Comparative Example 1–26

The comparative liquid crystal cells of Comparative Examples 1–23 to 1–26 differ from the configuration of the liquid crystal cell in Working Example 1–9 in that the alignment type has been changed from T–1 to T–2 through T–5.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–9. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cells of Comparative Examples 1–23 to 1–26 prepared in this manner are referred to as the comparative liquid crystal cells B23 to B26 in the following.

Working Example 1–10

The liquid crystal cell of Working Example 1–10 differs from the configuration of the liquid crystal cell of Working Example 1–4 in that the alignment type has been changed from H–1 to T–1.

The liquid crystal cell was prepared with the same method as in Working Example 1–4. Needless to say, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the aperture direction of the liquid crystal injection port 5 was arranged to be parallel to the alignment processing direction of the alignment film 1.

The liquid crystal cell of Working Example 1–10 prepared in this manner is referred to as the liquid crystal cell A10 in the following.

Comparative Example 1–27 to Comparative Example 1–30

The comparative liquid crystal cells of Comparative Examples 1–27 to 1–30 differ from the configuration of the liquid crystal cell in Working Example 1–10 in that the alignment type has been changed from T–1 to T–2 through T–5.

Moreover, the comparative liquid crystal cells were prepared by basically the same steps as in Working Example 1–9. Needless to say, in each of these comparative examples, the application of the sealing member 8 and the aligning of the first substrate 3 and the second substrate 4 was performed such that the angle β between the aperture direction of the liquid crystal injection port 5 and the line dividing the angle formed by the

alignment processing directions of the alignment film 1 and the alignment film 2 into two equal angles was set to a predetermined angle.

The liquid crystal cells of Comparative Examples 1–27 to 1–30 prepared in this manner are referred to as the liquid crystal cells B27 to B30 in the following.

Results

Making display screens with the liquid crystal cells A5 to A10 according to Working Examples 1–5 to 1–10 and with the liquid crystal cells B17 to B30 according to Comparative Examples 1–17 to 1–30 made as described above and examining them through a polarizer with the bare eye and with a polarization microscope, the results listed in the following Table 1–4 were obtained.

Table 1–4

type of liquid crystal cell	occurrence of flow alignment	alignment condition
liquid crystal cell A5	N	mono–domain
liquid crystal cell A6	N	mono–domain
liquid crystal cell A7	N	mono–domain
liquid crystal cell A8	N	mono–domain
liquid crystal cell A9	N	mono–domain
liquid crystal cell A10	N	mono–domain
comp. liquid crystal cell B17	Y	mono–domain
comp. liquid crystal cell B18	Y	mono–domain
comp. liquid crystal cell B19	Y	multi–domain
comp. liquid crystal cell B20	Y	mono–domain
comp. liquid crystal cell B21	Y	multi–domain
comp. liquid crystal cell B22	Y	mono–domain
comp. liquid crystal cell B23	Y	multi–domain
comp. liquid crystal cell B24	Y	mono–domain
comp. liquid crystal cell B25	Y	multi–domain
comp. liquid crystal cell B26	Y	mono–domain
comp. liquid crystal cell B27	Y	multi–domain
comp. liquid crystal cell B28	Y	mono–domain
comp. liquid crystal cell B29	Y	multi–domain
comp. liquid crystal cell B30	Y	mono–domain

N: no occurrence of flow alignment Y: occurrence of flow alignment

As becomes clear from Table 1–4, it was found that it is possible to

prevent flow alignment by arranging the direction dividing the intersection angle between the alignment processing direction of the alignment film 1 and the alignment processing direction of the alignment film 2 into two equal angles in parallel to the liquid crystal injection direction. Furthermore, it was also found that it is possible to prevent flow alignment by arranging the direction dividing the intersection angle between the alignment processing direction of the alignment film 1 and the alignment processing direction of the alignment film 2 into two equal angles substantially perpendicular to the liquid crystal injection direction.

(2) Embodiment According to the Second Aspect of the Invention

The following explains the second aspect of the present invention, with reference to the accompanying drawings.

In the liquid crystal display panel according to the second aspect of the present invention, the occurrence of flow alignment is eliminated or suppressed by optimizing the injection direction when injecting the liquid crystal, wherein, regarding all structural elements inside the liquid crystal cell, special consideration is given to the presence of at least one structural element that may become an obstacle when injecting the liquid crystal. Here, spacers (supporting members) for maintaining a constant cell gap are provided inside the liquid crystal cells, but in the present invention, no consideration is given to the influence of the spacers on the flow of the liquid crystal. The reason for this is that usually, the spacers are arranged at a distribution density of about 200 to 300 spacers per mm^2, arranged as dots

when viewed from above, so that they do not hinder the flow of the liquid crystal and do not cause flow alignment.

The following is a description of specific embodiments of IPS mode liquid crystal display panels, with and without color filter, in which the liquid crystal injection direction has been optimized.

Without Color Filter

Fig. 9 is a diagrammatical cross–sectional view of an IPS mode liquid crystal display panel. Fig. 10 is a diagrammatical plan view of a pair of electrodes, including a pixel electrode and an opposing electrode. Fig. 11 is a plan view schematically illustrating the liquid crystal injection direction and the liquid crystal flow direction when injecting liquid crystal into the empty cell.

As shown in Fig. 9, the liquid crystal display panel includes a lower substrate 21, an upper substrate 22 in opposition to the lower substrate 21, and a liquid crystal layer 23 disposed between the lower substrate 21 and the upper substrate 22. The lower substrate 21 and the upper substrate 22 are aligned together with a sealing member 29, and are made of glass substrates, for example.

A pixel electrode 24 and an opposing electrode 25 serving as an electrode pair as well as signal lines 28 for transmitting the signals necessary for driving the liquid crystal are arranged on the inner side of the lower substrate 21. Furthermore, an alignment film 26 for aligning nearby liquid crystal molecules in the same direction is disposed on the lower

substrate 21 including the pixel electrode 24 and the opposing electrode 25. On the other hand, an alignment film 27 for aligning nearby liquid crystal molecules in the same direction is disposed on the inner side of the upper substrate 22.

As shown in Fig. 10, the pixel electrode 24 includes a plurality of pixel electrode portions 24a and a coupling electrode portion 24b. The pixel electrode portions 24a have a plurality of bending points, and extending overall in the arrow direction Y, they are "〈"–shaped and bent at each of the bending points in alternating directions. Also the opposing electrode 25 has a similar shape as the pixel electrode 24 and includes a plurality of opposing electrode portions 25a and a coupling electrode portion 25b, the opposing electrode portions 25a being arranged in "〈"–shapes. The pixel electrode 24 and the opposing electrode 25 are disposed in an alternating arrangement, with the pixel electrode portions 24a interlocking with the opposing electrode portions 25a. Moreover, the extension direction of the pixel electrode portions 24a and the opposing electrode portions 25a is parallel to the alignment processing direction of the alignment films 26 and 27. Also, the pixel electrode 24 and the opposing electrode 25 are made, for example, of ITO (indium tin oxide) or aluminum. With an electrode arrangement as described above, it is possible to apply an electric field parallel to the substrate plane (transverse electric field) between the pixel electrode portions 24a and the opposing electrode portions 25a.

When injecting liquid crystal into an IPS mode liquid crystal display panel with this configuration, the pixel electrodes 24, the opposing

electrodes 25 and the signal lines 28 are the places where the liquid crystal flowing into a certain direction is subjected to the strongest resistance and which thus become the largest factor in causing flow alignment. Thus, the direction in which the influence of these structural elements causing flow resistance is diminished to a minimum should be taken as the liquid crystal injection direction. Here, "direction in which the influence of these structural elements causing flow resistance is diminished" means the direction with which the flow path in which the liquid crystal flows is ensured best, and which has the broadest empty portion. In the present invention, in order to determine the liquid crystal injection direction, the area ratios depending on the empty portion in projections of the liquid crystal cell are compared, and the liquid crystal injection direction is selected, for which this area ratio becomes largest.

As shown for example in Fig. 11(a), in the projection plane of a projection in a direction parallel to the extension direction of the pixel electrode portions 24a (or the opposing electrode portions 25a), the area ratio of the region in which the empty portion is projected onto the projection plane (the hatched region in Fig. 11(a)) is as follows: When $h_1 = 0.6\mu m$ is the height (film thickness) of the pixel electrode portions 24a and the opposing electrode portions 25a, $w_1 = 1.0\mu m$ is the electrode width, $h_2 = 0.6\mu m$ is the height (film thickness) of the signal lines 28 and $w_2 = 1.0\mu m$ is the electrode width, then the area ratio of the empty portion in one pixel is 90%. On the other hand, as shown in Fig. 11(b), in the projection plane of a projection in a direction perpendicular to the extension direction of the pixel

electrode portions 24a, the area ratio of the region in which the empty portion is projected onto the projection plane (the hatched region in Fig. 11(b)) is 80%. Thus, it becomes clear that it is preferable to take as the liquid crystal injection direction a direction parallel to the extension direction of the pixel electrode portions 24a (or the opposing electrode portions 25a). Here, it was assumed that the cell gap is 3μm.

Based on the previous considerations, in a liquid crystal display panel with the above-described configuration, the liquid crystal injection port 30 was arranged at the rim of an empty cell at a side perpendicular to the extension direction of the pixel electrode portions 24a (or the opposing electrode portions 25a) (see Fig. 12). It should be noted that the values for h_1, w_1, the area ratio etc., are merely illustrative values.

Thus, it is possible to let the liquid crystal injection direction coincide substantially with the extension direction of the longitudinal portion 32a, suppressing the influence of the electrode pair that may cause an obstacle to a minimum. This way, the occurrence of flow alignment can be reduced.

With Color Filter

Fig. 13 is a diagrammatical cross-sectional view of an IPS mode liquid crystal display panel with a color filter. Fig. 14 is a diagram illustrating the color filter. Fig. 14(a) is a partial plan view showing the R (red), G (green) and B (blue) color pattern of the color filter, Fig. 14(b) is a cross-sectional view taken in arrow direction along the line a – a' in Fig.

14(a), and Fig. 14(c) is a cross–sectional view taken in arrow direction along the line b – b' in Fig. 14(a).

IPS mode liquid crystal display panels suitable for color display differ from the configuration of the above–described liquid crystal display panels for black–and–white display in that a color filter 31 is disposed on the inner side of the upper substrate 22, as shown in Fig. 13.

As shown in Fig. 14(a), the color filter 31 includes a stripe–shaped RGB color pattern and a black matrix (light–blocking film) 32 optically separating the colors of the color pattern and preventing the colors from getting mixed.

As can be seen in Fig. 14(b), the black matrix 32 includes longer portions 32a and shorter portions 32b, and the relation $h_3 > h_4$ holds for the height (thickness) h_3 of the longer portions 32a and the height h_4 of the RGB portions. Furthermore, as can be seen in Fig. 14(c), the relation $h_3 > h_5$ holds for the height h_3 of the longer portions 32a and the height h_5 of the shorter portions 32b. On the other hand, as shown in Fig. 13, the relation between the height h_1 of the pixel electrode portions 24a (and the opposing electrode portions 25a), the height h_2 of the signal lines 28 and the height h_3 of the longer portions 32a of the black matrix 32 is $h_3 > h_1 = h_2$.

When injecting the liquid crystal into an IPS mode liquid crystal display panel with a color filter 31 configured as described above, the black matrix 32 exerts the strongest resistance on the liquid crystal flowing in a certain direction, thus becoming the largest factor in causing flow alignment. This is clearly so because the height h_3 of the longer portions 32a is higher

than the height h_1 of the pixel electrode portions 24a (or the opposing electrode portions 25a) and the height h_2 of the signal lines 28. In the case of liquid crystal display panels without a color filter 31, the electrodes pose a flow resistance to the liquid crystal flowing in a direction not parallel to the electrodes. Therefore, they may become a cause of flow alignment. However, when a color filter 31 is disposed on the upper substrate 22, this color filter 31 is the most prominent cause for flow alignment, because the black matrix 32 has a larger film thickness than the electrodes. Consequently, the liquid crystal injection direction should be the direction in which the influence of the black matrix 32 is reduced to a minimum.

As shown for example in Fig. 15(a), in the projection plane of a projection in a direction parallel to the longer portions 32a of the black matrix 32, the area ratio of the region in which the empty portion is projected onto the projection plane (the hatched region in Fig. 15(a)) is as follows: When $h_3 - h_4 = 0.8\mu m$ and $w_3 = 1.2\mu m$, then the area ratio of the empty portion in one pixel is 83.2%. On the other hand, as shown in Fig. 15(b), in the projection plane of a projection in a direction parallel to the shorter portions 32b of the black matrix 32, the area ratio of the region in which the empty portion is projected onto the projection plane (the hatched region in Fig. 15(b)) is 53.3%. Therefore, it becomes clear that it is preferable to take as the liquid crystal injection direction a direction parallel to the long portions 32a. Thus, in a liquid crystal display panel with a color filter 31, the liquid crystal injection port 33 is arranged at the rim of an empty cell at a side perpendicular to the extension direction of the longer

portions 32a in the black matrix 32 (see Fig. 16). Considering the fact that the relation between the film thickness h_1 of the longer portions 32a and the film thickness h_2 of the shorter portions 32b of the black matrix 32 is $h_1 > h_2$, it becomes easy to understand that it is advantageous to inject the liquid crystal from a direction parallel to the longer portions 32a. Also, the values for h_3, h_4, w_3, the area ratio etc., are merely illustrative values.

Thus, it is possible to let the liquid crystal injection direction coincide substantially with the extension direction of the longer portions 32a, suppressing the influence of the electrode pairs that may cause an obstacle to a minimum. This way, the occurrence of flow alignment can be reduced.

It should be noted that even though various thin films such as a protective film and an alignment film 27 etc. may be provided on the color filter 31, the black matrix 32 still forms protrusions and recessions leading to a flow resistance.

Further Considerations

The height of the electrodes (film thickness) in regular IPS mode liquid crystal display panels is substantially the same as the height of a TFT (thin film transistor, not shown in the drawings), but it is clear that the electrodes exert the greatest influence on the flow of the liquid crystal, because comparing the area that the TFTs occupies on the substrate surface with the area occupied by the electrodes, it can be seen that the TFTs are arranged in dots when viewed from above. Therefore, when the liquid crystal flows in a certain direction, the TFTs do not pose an obstacle

resulting in flow alignment or the like, so that the TFTs do not have to be considered when deciding the position and orientation of the liquid crystal injection port.

Also, this embodiment has been explained with an example, in which the extension direction of the electrodes and/or the longer portions of the black matrix are parallel to the alignment processing direction of the alignment films 26 and 27. However, the alignment processing direction of the alignment films 26 and 27 does not necessarily have to match with the extension direction of the electrodes and/or the longer portions of the black matrix, because the effect of suppressing the occurrence of flow alignment is accomplished by arranging at least the liquid crystal injection direction and the extension direction of the electrodes and/or the longer portions of the black matrix in parallel. The reason that flow alignment can be suppressed is that when structural elements posing a flow resistance to the liquid crystal flow are present inside the liquid crystal cell, this presence of structural elements posing a flow resistance has a larger influence on the occurrence of flow alignment than a mismatch between the liquid crystal injection direction and the alignment processing direction.

Moreover, the liquid crystal injection can be performed at room temperature and regular pressure, at high temperature and regular pressure, at room temperature and reduced pressure, or at high temperature and reduced pressure. Especially when the liquid crystal injection is performed at high temperature and reduced pressure, the flowability of the liquid crystal can be increased by the heat, and the liquid

crystal injection into the empty cell can be accelerated by the pressure reduction. When applying heat during the liquid crystal injection, it is preferable that, depending on the liquid crystal material, the temperature is equal to or higher than the phase transition temperature (T_{NI}) of the liquid crystal and not higher than T_{NI} + 30°. When the temperature is lower than T_{NI}, then a sufficient liquid crystal flowability cannot be attained, which is not desirable. On the other hand, when the temperature is higher than T_{NI} + 30°, then the liquid crystal deteriorates, which is not desirable.

This embodiment is a non–limiting example, and various design variations that do not stray from the scope of the present invention will be apparent to the person skilled in the art. For example, this embodiment has been explained for the case of IPS mode, but the present invention is not limited to this, and the present invention can also be applied to other display modes.

However, when there is a plurality of directions in which the area ratio of the region of the empty space projected onto a projection plane becomes maximal, then a direction should be chosen, in which the flow path for flowing the liquid crystal can be ensured best. Let us consider for example structural elements 35 posing a flow resistance, that are shaped like rectangular solids with length L, width W (L = 3W), and height H, as shown in Fig. 17(a). The liquid crystal cell 36 is a regular square, and S is its projection area with respect to the X direction as well as with respect to the Y direction. In a projection in the X direction (Fig. 17(b)), the area S_1 of the region that the empty portion occupies in the projection plane is S_1 = (S

$- L \times H$). On the other hand, in a projection in the Y direction (Fig. 17(c)), the area S_2 of the region that the empty portion occupies in the projection plane is $S_2 = (S - 3 \times W \times H)$. Since the relation $L = 3W$ is satisfied, this results in $S_1 = S_2$. Thus, in this case, it is not possible to decide on a liquid crystal injection direction. However, in this case, as becomes clear from the drawings, Y is the direction in which the flow path of the liquid crystal is ensured best. Consequently, the liquid crystal injection port should be arranged such that the liquid crystal injection direction is substantially parallel to the Y direction.

It is also possible to provide a plurality of liquid crystal injection ports. For example, depending on the size of the liquid crystal display panel, it is possible to provide 1 to 3 on one side of an empty cell rim. Moreover, it is also possible to provide liquid crystal injection ports on one side of the empty cell rim and on another side in opposition thereto.

Also, there is no particular limitation with regard to the alignment films 26 and 27 in this embodiment, and the alignment films 26 and 27 can be silane–based organic thin films, polyamide films or the like. In case of silane–based organic thin films, they can be monomolecular adsorption films or polymer adsorption films. Here, "monomolecular adsorption film" refers to a thin film which can be regarded roughly as a monomolecular film. For example, the monomolecular adsorption film may include a portion in which molecules that are not yet adsorbed have accumulated on top of molecules that are adsorbed to the substrate, resulting in a layer of a plurality of molecules, or a portion of the thin film may be missing, for example in a

portion where the molecules have not adsorbed to the substrate.

Furthermore, it is preferable that the alignment films 26 and 27 described for the present embodiment are alignment processed by a process such as rubbing or photoalignment with polarized UV light. Especially when carrying out a photoalignment process, it is possible to use alignment films including compounds with photosensitive groups, in which a photoreaction such as a photocrosslinking reaction or a photolytic reaction can be induced for example by irradiation with polarized UV light.

Furthermore, it is also possible to dispose a primer layer between the alignment film 26 and the lower substrate 21 and/or between the alignment film 27 and the upper substrate 22. There is no particular limitation regarding such a primer layer, and examples for suitable primer layers include inorganic chlorosilane–based polymer films, polysilazane films (made by Tonen Corp.) and silicon dioxide (SiO_2) films. For example, when arranging an inorganic chlorosilane–based polymer film on a substrate provided with a silicon nitride film serving as an insulating film, the substrate surface can be made hydrophilic, so that when the alignment film is made of clusters of chemisorptive molecules, these chemisorptive molecules can be chemically adsorbed with high density. As a result, it is possible to form alignment films with excellent durability. Moreover, it is preferable that the thickness of the primer layer is equal or greater than the step resulting between the signal lines, between the electrodes and between the signal lines and the electrodes. More specifically it is preferable that that the thickness of the primer layer is in the range of 150nm to 5μm.

Thus, the occurrence of flow alignment can be suppressed even better.

Furthermore, even in the case of IPS mode, the electrodes are not limited to “<”–shapes as in the example of the present embodiment. For example, as shown in Fig. 18(a), they can also be arranged as stripe–shaped parallel electrode pairs 37. Alternatively, they can also be arranged as electrode pairs 38 with a series of hook–shaped electrode portions including long sides 38a and short sides 38b, with both ends pointing in different directions, as shown in Fig. 18(b). It should be noted that the angle between the long sides 38a and the short sides 38b can be modified as suitable.

<u>Working Examples</u>

Referring to the accompanying drawings, the following is a more detailed explanation of preferable working examples of the present invention. However, it should be understood that, if not noted otherwise, the dimensions, material, shapes, relative arrangement etc. of the structural elements described in these working examples are not limiting upon the scope of the present invention, and are merely illustrative examples.

“<”–shaped electrodes

<u>Working Example 2–1</u>

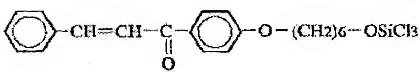
The following is a detailed explanation of a preferable working example of the present invention.

First, the pair of substrates used for Working Example 2–1 is

explained. The substrates used in this working example are made of glass, and "⟨"–shaped electrodes **41** made of aluminum, signal lines (not shown in the drawings), and a silicon nitride film (insulating film) of 360nm film thickness covering the electrodes **41** are disposed on the inner side of one of the substrates (electrode substrate), as shown in Fig. 19. The electrodes **41** are bent in alternation in different directions at bending points, and are formed to extend overall in a predetermined direction.

Then a silane–based surfactant including molecules with the functional group (C_6H_5–CH=CH–CO–C_6H_4–O–CH_2–O–) having a chalcone group (see structural formula (1)) was dissolved to a concentration of 0.2wt% in a non–aqueous organic solvent made of thoroughly dehydrated chloroform, thus preparing a chemical adsorption solution.

Formula (1)



Then, the sufficiently degreased and rinsed substrate pair was immersed for one hour in the chemical adsorption solution. With this process, it was possible to adsorb the adsorption molecules on the surface of the electrode substrate and the substrate with the color filter.

Next, the substrate pair was immersed under an anhydrous atmosphere in a solvent such as chloroform, washing off the non–adsorbed

molecules. It should be noted that when the washing is performed in a regular atmosphere, it is possible to form a polymer adsorption film by reacting the non–adsorbed molecules with the water content in the air, for example. Also, lifting the substrates from one side, the adsorption molecules that were coupled and fastened to the substrate surface were tilted to the direction opposite the tilt direction. Thus, it was possible to form a siloxane–based monomolecular film (alignment film) made of clusters of adsorption molecules covalently bonded with siloxane bonds to the substrate surface. When the electrode substrate was lifted out of the chloroform, the lifting direction was set to coincide substantially with the extension direction of the electrodes 41.

Then, the alignment films were alignment processed by photoalignment. In this case of photoalignment processing, the alignment direction of the film molecules with respect to the polarization direction of the polarized UV light differs depending on the reaction (decomposition or polymerization) of the photosensitive groups of the film molecules (adsorption molecules) constituting the alignment films and the tilt direction of the film molecules. Giving consideration to this fact, the polarized UV light was irradiated on the surface of the alignment films in this working example such that the polarization direction of the polarized UV light was parallel to the above–described lifting direction (i.e. the extension direction of the electrodes 41). Thus, the chalcone groups serving as the photosensitive groups were polymerized in a direction parallel to the polarization direction, and alignment films with crosslinked film molecules

were formed.

In this working example, the photoalignment processing was carried out such that the alignment processing direction was the same direction for the entire alignment film, but the present invention is not limited to this. For example, it is also possible to perform a partitioned alignment process, in which one pixel is partitioned into a plurality of regions. In that case, different alignment processing directions can be attained for each region by irradiating polarized UV light in which the polarization direction differs for each irradiated region through a mask using photoresist.

It should be noted that although monomolecular alignment films made of clusters of film molecules including photosensitive groups were used in this working example, it is also possible to use alignment films made of polyimide. For that case, polyimide is dissolved and diluted in n–methyl pyrrolidinone such that the film thickness after the film formation is 50nm, and after applying this solution on the substrate with a spinner or the like, it is dried and baked to form the film.

Next, the electrode substrate and the opposing substrate were aligned together such that the alignment films formed in this manner are arranged in opposition, thus forming an empty cell. More specifically, a sealing member was formed by screen printing on the surface of the electrode substrate on which the alignment film is formed, such that the application shape is formed like a rectangular frame. By leaving a portion of this rectangular frame open, an aperture portion (liquid crystal injection port) was formed. It is preferable that the sealing member is made of a

solventless epoxy resin exerting only little negative influence on the alignment of the liquid crystal, but it is also possible to use an epoxy resin with silicon oil removed. Furthermore, the aperture portion was formed at the middle of the side of the substrate that was opposite from the direction in which the substrate was lifted when washing. Thus, the liquid crystal injection direction was matched with the alignment processing direction. Furthermore, spacers were spread over the electrode substrate, and the electrode substrate and the opposing substrate were aligned together at a cell gap of about 3.1μm. The liquid crystal injection port was formed at the location of the aperture portion at this time. The alignment processing directions of the alignment films on the electrode substrate and the opposing substrate were set to be anti–parallel. Then, the empty cell was inserted into a vacuum pack to be evacuated, and the cell gap was equalized.

Then, the liquid crystal was injected into the empty cell. That is to say, the liquid crystal injection port (aperture portion, sealing member opening) facing downward, the empty cell was placed in a vacuum chamber equipped with a heater, and a liquid crystal reservoir filled to the brim with liquid crystal (trade name: MJ–97254, by Merck Corp.) was placed directly below it. Thus, the liquid crystal injection direction (flow direction of the liquid crystal) was matched substantially with the extension direction of the electrodes 41. Subsequently, while evacuating the vacuum chamber, the vacuum chamber was heated with the heater to the curing temperature of the adhesive (sealing member), and left in that state for about 15min. The

heating time can be set as appropriate depending on the type of adhesive used, and to be more specific, it is preferable to set the heating time to about 15 to 120min, and considering temporal and operative efficiency, more preferably to about 15min.

After that, the temperature was reduced to the N–I phase transition temperature of the liquid crystal, and the liquid crystal was injected into the empty cell by bringing the liquid crystal injection port of the empty cell into contact with the liquid crystal reservoir, leaking, and returning the vacuum to atmospheric pressure. After the injection of the liquid crystal into the empty cell was terminated, the power to the heater was interrupted, and the liquid crystal cell was cooled off naturally. After the liquid crystal cell was returned to room temperature, it was retrieved from the vacuum chamber, and the liquid crystal injection port was sealed with a UV curing adhesive, which was cured by irradiating a UV light spot on the sealed portion. Thus, a liquid crystal cell with a liquid crystal layer of parallel alignment structure was produced.

Next, a pair of polarizers was arranged on the outer sides of the liquid crystal cell, satisfying certain optical conditions, and a liquid crystal display panel C1 in accordance with the present invention was obtained. Then, this liquid crystal display panel C1 was subjected to an alignment evaluation. As the optical conditions, the transmission axis of one of the pair of polarizers is set to coincide with the alignment direction of the liquid crystal, whereas the transmission axis of the other polarizer is set to be perpendicular to this alignment direction.

First of all, the alignment of the liquid crystal display panel C1 was evaluated. When the initial alignment of the liquid crystal display panel C1 was examined with the bare eye, very little flow alignment could be observed near the liquid crystal injection port. Moreover, when the liquid crystal display panel C1 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could be eliminated completely. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 were substantially matching one another, and an IPS mode liquid crystal display panel C1 with homogeneous alignment was obtained. Here, the region 42 and the region 43 are the regions enclosed by the electrodes 41 in Fig. 19.

Furthermore, the pretilt angle (θp) of the liquid crystal display panel C1 measured with a pretilt angle measuring device using the crystal rotation method was 0.3°. Furthermore, the evaluation of the contrast was performed as follows. When the liquid crystal was injected into the empty cell, a liquid crystal test cell was produced using liquid crystal material made by mixing black pigments into the liquid crystal, and the luminance for the bright state and the dark state was measured through one polarizer to determine the contrast ratio, which is the ratio between white luminance and black luminance. As a result, a contrast ratio of 370 was determined.

Comparative Example 2–1

The comparative liquid crystal display panel of Comparative

Example 2–1 differs from the liquid crystal display panel in Working Example 2–1 in that the liquid crystal display panel was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–1 prepared in this manner is referred to as the comparative liquid crystal display panel D1 in the following.

The alignment of the comparative liquid crystal display panel D1 was evaluated in the same manner as for Working Example 2–1. When the initial alignment of the comparative liquid crystal display panel D1 was examined with the bare eye, flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D1 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 did not match.

Furthermore, as in Working Example 2–1, the pretilt angle of the comparative liquid crystal display panel D1 was measured to be 0.3°. Also, evaluated in the same manner as for Working Example 2–1, the contrast ratio was 180.

<u>Working Example 2–2</u>

The liquid crystal display panel according to Working Example 2–2 has almost the same configuration as the liquid crystal display panel

according to Working Example 2–1, but its manufacturing method was different in that it was produced using the following chemical adsorption solution instead of the above–mentioned chemical adsorption solution. That is to say, in this working example, n–octadecyl trichlorosilane as given in Structural Formula (2) was dissolved to ca. 1wt% and mixed with the above–described chemical adsorption solution in a mixing ratio of 4 : 1. Then, this mixed solution was dissolved to a concentration of 0.2wt% in thoroughly dehydrated chloroform (non–aqueous organic solvent), thus producing the chemical adsorption solution of this working example.

Formula (2) $CH_3(CH_2)_{17}SiCl_3$

The liquid crystal display panel of this working example produced using this chemical adsorption solution is referred to as the liquid crystal display panel C2 in the following.

The alignment of the liquid crystal display panel C2 was evaluated in the same manner as for Working Example 2–1. When the initial alignment of the liquid crystal display panel C2 was examined with the bare eye, no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 were substantially matching one another, and an IPS mode liquid

crystal display panel C1 with homogeneous alignment was obtained.

Furthermore, measuring the pretilt angle of the liquid crystal display panel C2 in the same manner as in Working Example 2–1 resulted in a pretilt angle of 0.5°. Also, the contrast ratio, evaluated in the same manner as for Working Example 2–1, was 340.

Comparative Example 2–2

The comparative liquid crystal display panel of Comparative Example 2–2 has substantially the same configuration as the liquid crystal display panel in Working Example 2–2, but its manufacturing method differs in that the liquid crystal display panel was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–2 produced in this manner is referred to as the comparative liquid crystal display panel D2 in the following.

The alignment of the comparative liquid crystal display panel D2 was evaluated in the same manner as for Working Example 2–1. When the initial alignment of the comparative liquid crystal display panel D2 was examined with the bare eye, flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D2 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions

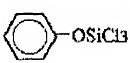
42 and 43 did not match.

Furthermore, measuring the pretilt angle of the comparative liquid crystal display panel D2 in the same manner as in Working Example 2–1 resulted in a pretilt angle of 0.3°. Also, the contrast ratio, evaluated in the same manner as for Working Example 2–1, was 155.

<u>Working Example 2–3</u>

The liquid crystal display panel according to Working Example 2–3 has almost the same configuration as the liquid crystal display panel according to Working Example 2–1, but its manufacturing method differs in that it was produced using the following chemical adsorption solution instead of the above–mentioned chemical adsorption solution. That is to say, in this working example, phenyltrichlorosilane as given in Structural Formula (3) was dissolved to ca. 1wt% and mixed with the above–described chemical adsorption solution in a mixing ratio of 1 : 1. Then, this mixed solution was dissolved to a concentration of 0.2wt% in thoroughly dehydrated chloroform (non–aqueous organic solvent), thus obtaining the chemical adsorption solution of this working example. The liquid crystal display panel of this working example produced with this chemical adsorption solution is referred to as the liquid crystal display panel C3.

Formula (3)



The alignment of the liquid crystal display panel C3 was evaluated in the same manner as for Working Example 2–1. When the initial alignment of the liquid crystal display panel C3 was examined with the bare eye, no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 were substantially matching one another, and an IPS mode liquid crystal display panel C3 with homogeneous alignment was obtained.

Furthermore, measuring the pretilt angle of the liquid crystal display panel C3 in the same manner as in Working Example 2–1 resulted in a pretilt angle of 0.3°. Also, the contrast ratio, evaluated in the same manner as for Working Example 2–1, was 325.

<u>Comparative Example 2–3</u>

The comparative liquid crystal display panel of Comparative Example 2–3 has substantially the same configuration as the liquid crystal display panel in Working Example 2–3, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–3 produced in this manner is referred to as the comparative liquid crystal display panel D3 in the following.

The alignment of the comparative liquid crystal display panel D3 was evaluated in the same manner as for Working Example 2–1. When the

initial alignment of the comparative liquid crystal display panel D3 was examined with the bare eye, flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D3 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 did not match.

Furthermore, measuring the pretilt angle of the comparative liquid crystal display panel D3 in the same manner as in Working Example 2–3 resulted in a pretilt angle of 0.3°. Also, the contrast ratio, evaluated in the same manner as for Working Example 2–1, was 108.

"⟨"–shaped Electrodes, Primer Layer

<u>Working Example 2–4</u>

The liquid crystal display panel according to Working Example 2–4 differs greatly from the liquid crystal display panel according to Working Example 2–1 in that the alignment film is provided on a substrate provided with a primer layer made of SiO_2.

The pair of substrates used in this working example is made of glass, and "⟨"–shaped electrodes made of aluminum and signal lines are disposed on the inner side of one of the substrates (electrode substrate). However, no silicon nitride film covering the electrodes (insulating film) is formed on this electrode substrate.

Then, an inorganic chlorosilane agent ($SiCl_3OSiCl_3$) was dissolved in hexamethyldisiloxane (non–aqueous solvent, bp. 100°C) to prepare a chemical adsorption solution of ca. 3wt% concentration. For this, thoroughly dehydrated hexamethyldisiloxane was used. It is preferable that the concentration of the chemical adsorption solution is in the range of 0.1 to 50wt%, more preferably in the range of 1 to 5wt%.

Then, the sufficiently degreased and rinsed substrate pair was immersed for one minute in the chemical adsorption solution in a dry atmosphere (with ca. 5% relative humidity).

After that, the substrate pair was retrieved from the chemical adsorption solution, and the solvent (hexamethyldisiloxane) was evaporated under a dry atmosphere (with about 5% humidity). Thus, the film 44 shown in Fig. 20(a) could be formed. When the substrate pair provided with the film 44 was exposed to air including a certain water content, the water content in the air and the chlorosilyl groups underwent a dehydrochlorination reaction forming a primer layer 45 made of an inorganic siloxane polymer film having numerous hydroxyl groups (see Fig. 20(b)). In accordance with the present invention, it was also possible to use $SiCl_4$ or compounds that can be represented by $(SiCl_2O)_nSiCl_3$ (wherein n is the integer 2 or 3) instead of $SiCl_3OSiCl_3$. Especially when ITO was used for the electrodes, it was confirmed that $(SiCl_2O)_nSiCl_3$ could deliver hydroxyl groups to the ITO surface and the effect of making the electrode surface hydrophilic was even stronger.

Then, the alignment films were formed on the primer layer 45 in the

same manner as in Working Example 2–1. And as in Working Example 2–1, the electrode substrate and the opposing substrate were aligned together such that the alignment films were arranged in opposition, forming an empty cell, and liquid crystal was injected into the empty cell by vacuum injection to produce a liquid crystal cell. The liquid crystal display panel of Working Example 2–4 produced in this manner is referred to as the liquid crystal display panel C4 in the following.

The alignment of the liquid crystal display panel C4 was evaluated in the same manner as for Working Example 2–1. When the initial alignment of the liquid crystal display panel C4 was examined with the bare eye, no flow alignment could be observed.

Comparative Example 2–4

The comparative liquid crystal display panel of Comparative Example 2–4 differs from the liquid crystal display panel in Working Example 2–4 in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–4 produced in this manner is referred to as the comparative liquid crystal display panel D4 in the following.

The alignment of the comparative liquid crystal display panel D4 was evaluated in the same manner as for Working Example 2–4. When the initial alignment of the comparative liquid crystal display panel D4 was examined with the bare eye, flow alignment could be observed near the

liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D4 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, the alignment directions in the neighboring regions 42 and 43 did not match.

Results

The evaluation results of the alignment of the liquid crystal display panels C1 to C4 according to Working Examples 2–1 to 2–4 and the comparative liquid crystal display panels D1 to D4 according to Comparative Examples 2–1 to 2–3 made as described above are listed in the following Table 2–1.

Table 2–1

	liquid crystal injection direction	occurrence of flow alignment	alignment condition	pretilt angle	contrast
Working Example 2–1	parallel to elect–rode extension direction	flow alignment yes→ eliminated after annealing	mono–domain	0.3	370
Working Example 2–2	parallel to elect–rode extension direction	flow alignment yes→ eliminated after annealing	mono–domain	0.5	340
Working Example 2–3	parallel to elect–rode extension direction	flow alignment yes→ eliminated after annealing	mono–domain	0.3	325
Working Example 2–4	parallel to elect–rode extension direction	no flow alignment	mono–domain	–	–
Comparative Example 2–1	perpendicular to electrode exten–sion direction	flow alignment yes→ remains after annealing	multi–domain	0.3	180
Comparative Example 2–2	perpendicular to electrode exten–sion direction	flow alignment yes→ remains after annealing	multi–domain	0.3	155
Comparative Example 2–3	perpendicular to electrode exten–sion direction	flow alignment yes→ remains after annealing	multi–domain	0.3	108
Comparative Example 2–4	perpendicular to electrode exten–sion direction	flow alignment yes→ remains after annealing	multi–domain	–	–

As becomes clear from Table 2–1, it is possible to suppress or prevent the occurrence of flow alignment and to obtain a liquid crystal display panel with high contrast by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes.

Moreover, as becomes clear from Working Examples 2–1 to 2—3, it was found that when a silane–based surfactant including molecules with C_6H_5–CH=CH–CO–C_6H_4–O–CH_2–O– groups including chalcone groups is

used alone, then a higher contrast can be attained than when using a mixed sample of the silane–based surfactant and n–octadecyl trichlorosilane.

Furthermore, in the liquid crystal display panel C4 provided with a primer layer, there was no flow alignment at all, and it was not necessary to perform annealing after the liquid crystal injection. This is because when forming the alignment film via a primer layer, the film molecules constituting the alignment films can be chemically adsorbed at a higher density and are less susceptible to the influence of the flow of the liquid crystal than when they are directly chemically adsorbed on the substrate.

<u>Working Example 2–5</u>

The liquid crystal display panel according to Working Example 2–5 differs from the liquid crystal display panel according to Working Example 2–1 in that a polymer film made of a polyimide resin instead of a siloxane–based monomolecular film is used for the alignment films.

The alignment film made of the polyimide resin was made as follows. A polyimide–based alignment film material (trade name: S–150 by Nissan Chemical Industries, Ltd.) was applied and baked, thus forming an alignment film. Then, the alignment film was alignment processed by rubbing. In this working example, a liquid crystal display panel with alignment films made of such a polymer film is referred to as liquid crystal display panel E1.

The alignment of the liquid crystal display panel C5 was evaluated in the same manner as for Working Example 2–1. First, the initial

alignment of the liquid crystal display panel C5 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

<u>Comparative Example 2–5</u>

The comparative liquid crystal display panel of Comparative Example 2–5 has substantially the same configuration as the liquid crystal display panel in Working Example 2–5, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–5 produced in this manner is referred to as the comparative liquid crystal display panel D5 in the following.

The alignment of the comparative liquid crystal display panel D5 was evaluated in the same manner as for Working Example 2–5. First, the initial alignment of the liquid crystal display panel D5 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D5 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that

the alignment condition of the liquid crystal was not homogeneous.

Working Example 2–6

The liquid crystal display panel according to Working Example 2–6 differs from the liquid crystal display panel according to Working Example 2–1 in that a photosensitive polyimide–based alignment film material (trade name: LPPR502CP, by Rolik Corp.) is used instead of the polyimide–based alignment film material (trade name: S–150 by Nissan Chemical Industries, Ltd.), and that for the alignment process, a photoalignment process was performed instead of the rubbing process. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel E2.

The alignment of the liquid crystal display panel C6 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel C6 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–6

The comparative liquid crystal display panel of Comparative Example 2–6 has substantially the same configuration as the liquid crystal display panel in Working Example 2–6, but its manufacturing method

differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–6 produced in this manner is referred to as the comparative liquid crystal display panel D6 in the following.

The alignment of the comparative liquid crystal display panel D6 was evaluated in the same manner as for Working Example 2–6. First, the initial alignment of the comparative liquid crystal display panel F1 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel D6 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

<u>Results</u>

The evaluation results of the alignment of the liquid crystal display panels C5 and C6 according to Working Examples 2–5 and 2–6 and the comparative liquid crystal display panels D5 and D6 according to Comparative Examples 2–5 and 2–6 made as described above are listed in the following Table 2–2.

Table 2–2

	liquid crystal injection direction	occurrence of flow alignment	alignment condition
Working Example 2–5	parallel to electrode extension direction	no flow alignment	mono–domain
Working Example 2–6	parallel to electrode extension direction	no flow alignment	mono–domain
Comparative Example 2–5	perpendicular to electrode extension direction	flow alignment yes ➔ remains after annealing	mono–domain
Comparative Example 2–6	perpendicular to electrode extension direction	flow alignment yes ➔ remains after annealing	multi–domain

As becomes clear from Table 2–2, it was found that it is possible to suppress or prevent the occurrence of flow alignment and to obtain a liquid crystal display panel having high contrast and with an alignment film made of a polymer film by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes.

Stripe–Shaped Parallel Electrode Pair

Parallel Electrodes

Working Example 2–7

The liquid crystal display panel according to Working Example 2–7 differs from the liquid crystal display panel according to Working Example 2–1 in that stripe–shaped parallel electrode pairs are used instead of the "<"–shaped electrodes. The liquid crystal display panel according to this

working example is referred to as liquid crystal display panel E1.

The alignment of the liquid crystal display panel E1 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel E1 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

<u>Comparative Example 2–7</u>

The comparative liquid crystal display panel of Comparative Example 2–7 has substantially the same configuration as the liquid crystal display panel in Working Example 2–7, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–7 produced in this manner is referred to as the comparative liquid crystal display panel F1 in the following.

The alignment of the comparative liquid crystal display panel F1 was evaluated in the same manner as for Working Example 2–5. First, the initial alignment of the comparative liquid crystal display panel F1 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel F1 was

annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Primer Layer, Parallel Electrodes

Working Example 2–8

The liquid crystal display panel according to Working Example 2–8 differs from the liquid crystal display panel C4 according to Working Example 2–4 in that stripe–shaped parallel electrode pairs are used instead of the "〈"–shaped electrodes. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel E2.

The alignment of the liquid crystal display panel E2 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel E2 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–8

The comparative liquid crystal display panel of Comparative Example 2–8 has substantially the same configuration as the liquid crystal

display panel in Working Example 2–8, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–8 produced in this manner is referred to as the comparative liquid crystal display panel F2 in the following.

The alignment of the comparative liquid crystal display panel F2 was evaluated in the same manner as for Working Example 2–8. First, the initial alignment of the comparative liquid crystal display panel F2 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel F2 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Results

The evaluation results of the alignment of the liquid crystal display panels E1 and E2 according to Working Examples 2–7 and 2–8 and the comparative liquid crystal display panels F1 and F2 according to Comparative Examples 2–7 and 2–8 made as described above are listed in the following Table 2–3.

Table 2–3

	liquid crystal injection direction	occurrence of flow alignment	alignment condition
Working Example 2–7	parallel to electrode extension direction	no flow alignment	mono–domain
Working Example 2–8	parallel to electrode extension direction	no flow alignment	mono–domain
Comparative Example 2–7	perpendicular to electrode extension direction	flow alignment yes ➔ remains after annealing	multi–domain
Comparative Example 2–8	perpendicular to electrode extension direction	flow alignment yes ➔ remains after annealing	multi–domain

As becomes clear from Table 2–3, it was found that it is possible to obtain a liquid crystal display panel in which the occurrence of flow alignment is suppressed by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes. In particular, flow alignment did not occur even when the alignment film was formed without a primer layer, as in the case of the liquid crystal display panel E1 according to Working Example 2–7. It seems that the reason for this is that parallel electrode pairs pose less flow resistance than "〈"–shaped electrodes.

Working Example 2–9

The liquid crystal display panel according to Working Example 2–9 differs from the liquid crystal display panel according to Working Example 2–5 in that a polymer film made of a polyimide resin instead of a

siloxane–based monomolecular film is used for the alignment films. The liquid crystal display panel of this working example with alignment films made of such a polyimide resin is referred to as liquid crystal display panel E3.

The alignment of the liquid crystal display panel E3 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel E3 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–9

The comparative liquid crystal display panel of Comparative Example 2–9 has substantially the same configuration as the liquid crystal display panel in Working Example 2–9, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–9 produced in this manner is referred to as the comparative liquid crystal display panel F3 in the following.

The alignment of the comparative liquid crystal display panel F3 was evaluated in the same manner as for Working Example 2–9. First, the initial alignment of the comparative liquid crystal display panel F3 was

examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel F3 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Working Example 2–10

The liquid crystal display panel according to Working Example 2–10 differs from the liquid crystal display panel according to Working Example 2–9 in that a photosensitive polyimide–based alignment film material (trade name: LPPR502CP, by Rolik Corp.) is used instead of the polyimide–based alignment film material (trade name: S–150 by Nissan Chemical Industries, Ltd.), and that for the alignment process, a photoalignment process was performed instead of the rubbing process. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel E4.

The alignment of the liquid crystal display panel E4 was evaluated in the same manner as for Working Example 2–9. First, the initial alignment of the liquid crystal display panel E4 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was

observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–10

The comparative liquid crystal display panel of Comparative Example 2–10 has substantially the same configuration as the liquid crystal display panel in Working Example 2–10, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–10 produced in this manner is referred to as the comparative liquid crystal display panel F4 in the following.

The alignment of the comparative liquid crystal display panel F4 was evaluated in the same manner as for Working Example 2–10. First, the initial alignment of the comparative liquid crystal display panel F4 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel F4 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Results

The evaluation results of the alignment of the liquid crystal display panels E3 and E4 according to Working Examples 2–9 and 2–10 and the comparative liquid crystal display panels F3 and F4 according to Comparative Examples 2–9 and 2–10 made as described above are listed in the following Table 2–4.

Table 2–4

	liquid crystal injection direction	occurrence of flow alignment	alignment condition
Working Example 2–9	parallel to electrode extension direction	no flow alignment	mono–domain
Working Example 2–10	parallel to electrode extension direction	no flow alignment	mono–domain
Comparative Example 2–9	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	mono–domain
Comparative Example 2–10	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	mono–domain

As becomes clear from Table 2–4, it was found that by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes, it is possible to obtain a liquid crystal display panel in which the occurrence of flow alignment is suppressed, even when the alignment films are made of polymer films.

Electrode Pairs Having Long and Short Sides

Working Example 2–11

The liquid crystal display panel according to Working Example 2–11 differs from the liquid crystal display panel according to Working Example 2–1 in that hook–shaped electrode pairs having long and short sides are used instead of the "<"–shaped electrodes. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel G1.

The alignment of the liquid crystal display panel G1 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel G1 was examined with the bare eye. As the result, it was found that although flow alignment could be observed near the liquid crystal injection port, this flow alignment could be eliminated by performing an annealing process. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–11

The comparative liquid crystal display panel of Comparative Example 2–11 has substantially the same configuration as the liquid crystal display panel in Working Example 2–11, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–11 produced in this manner is referred to as the comparative liquid crystal display panel H1 in the following.

The alignment of the comparative liquid crystal display panel H1 was evaluated in the same manner as for Working Example 2–11. First, the initial alignment of the comparative liquid crystal display panel H1 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel H1 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Working Example 2–12

The liquid crystal display panel according to Working Example 2–12 differs from the liquid crystal display panel according to Working Example 2–4 in that hook–shaped electrode pairs having long and short sides are used instead of the "〈"–shaped electrodes. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel G2.

The alignment of the liquid crystal display panel E2 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel G2 was examined with the bare eye. As the result, it was found that although flow alignment could be observed near the liquid crystal injection port, this flow alignment could be

eliminated by performing an annealing process. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–12

The comparative liquid crystal display panel of Comparative Example 2–12 has substantially the same configuration as the liquid crystal display panel in Working Example 2–12, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–6 produced in this manner is referred to as the comparative liquid crystal display panel H2 in the following.

The alignment of the comparative liquid crystal display panel H2 was evaluated in the same manner as for Working Example 2–6. First, the initial alignment of the comparative liquid crystal display panel H2 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel H2 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Results

The evaluation results of the alignment of the liquid crystal display panels G1 and G2 according to Working Examples 2–11 and 2–12 and the comparative liquid crystal display panels H1 and H2 according to Comparative Examples 2–11 and 2–12 made as described above are listed in the following Table 2–5.

Table 2–5

	liquid crystal injection direction	occurrence of flow alignment	alignment condition
Working Example 2–11	parallel to electrode extension direction	flow alignment yes → eliminated after annealing	multi–domain
Working Example 2–12	parallel to electrode extension direction	flow alignment yes → eliminated after annealing	multi–domain
Comparative Example 2–11	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	multi–domain
Comparative Example 2–12	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	multi–domain

As becomes clear from Table 2–5, by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes, it is possible to obtain a liquid crystal display panel in which the occurrence of flow alignment is suppressed.

Working Example 2–13

The liquid crystal display panel according to Working Example 2–13

differs from the liquid crystal display panel according to Working Example 2–11 in that a polymer film made of a polyimide resin instead of a siloxane–based monomolecular film is used for the alignment films. The liquid crystal display panel of this working example with alignment films made of such a polyimide resin is referred to as liquid crystal display panel G3.

The alignment of the liquid crystal display panel G3 was evaluated in the same manner as for Working Example 2–1. First, the initial alignment of the liquid crystal display panel G3 was examined with the bare eye. As the result, it was found that although flow alignment could be observed near the liquid crystal injection port, this flow alignment could be eliminated by performing an annealing process. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

Comparative Example 2–13

The comparative liquid crystal display panel of Comparative Example 2–13 has substantially the same configuration as the liquid crystal display panel in Working Example 2–13, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–13 produced in this manner is referred to as the comparative liquid crystal display panel H3 in the following.

The alignment of the comparative liquid crystal display panel H3 was evaluated in the same manner as for Working Example 2–13. First, the initial alignment of the comparative liquid crystal display panel H3 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel H3 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

<u>Working Example 2–14</u>

The liquid crystal display panel according to Working Example 2–14 differs from the liquid crystal display panel according to Working Example 2–13 in that a photosensitive polyimide–based alignment film material (trade name: LPPR502CP, by Rolik Corp.) is used instead of the polyimide–based alignment film material (trade name: S–150 by Nissan Chemical Industries, Ltd.), and that for the alignment process, a photoalignment process was performed instead of the rubbing process. The liquid crystal display panel according to this working example is referred to as liquid crystal display panel G4.

The alignment of the liquid crystal display panel G4 was evaluated in the same manner as for Working Example 2–13. First, the initial

alignment of the liquid crystal display panel G4 was examined with the bare eye. As the result, it was found that no flow alignment could be observed near the liquid crystal injection port. Also, when the alignment was observed in more detail with a polarization microscope, a homogeneous alignment condition could be ascertained.

<u>Comparative Example 2–14</u>

The comparative liquid crystal display panel of Comparative Example 2–14 has substantially the same configuration as the liquid crystal display panel in Working Example 2–14, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction perpendicular to the extension direction of the electrodes. The liquid crystal display panel of Comparative Example 2–14 produced in this manner is referred to as the comparative liquid crystal display panel H4 in the following.

The alignment of the comparative liquid crystal display panel H4 was evaluated in the same manner as for Working Example 2–14. First, the initial alignment of the comparative liquid crystal display panel H4 was examined with the bare eye. As the result, it was found that flow alignment could be observed near the liquid crystal injection port. Moreover, even though the comparative liquid crystal display panel H4 was annealed at a temperature above the phase transition temperature of the liquid crystal, the flow alignment could not be eliminated. Also, when the alignment was observed in more detail with a polarization microscope, it

could be ascertained that the alignment condition of the liquid crystal was not homogeneous.

Results

The evaluation results of the alignment of the liquid crystal display panels G3 and G4 according to Working Examples 2–13 and 2–14 and the comparative liquid crystal display panels H3 and H4 according to Comparative Examples 2–13 and 2–14 made as described above are listed in the following Table 2–4.

Table 2–6

	liquid crystal injection direction	occurrence of flow alignment	alignment condition
Working Example 2–13	parallel to electrode extension direction	flow alignment yes → eliminated after annealing	multi–domain
Working Example 2–14	parallel to electrode extension direction	flow alignment yes → eliminated after annealing	multi–domain
Comparative Example 2–13	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	multi–domain
Comparative Example 2–14	perpendicular to electrode extension direction	flow alignment yes → remains after annealing	multi–domain

As becomes clear from Table 2–4, it was found that by arranging the liquid crystal injection direction parallel to the extension direction of the electrodes, it is possible to obtain a liquid crystal display panel in which the occurrence of flow alignment is suppressed, even when the alignment films are made of polymer films.

Working Example 2–15

First, the substrate pair used in Working Example 2–15 is explained. For one of the two substrates used in the working example, the electrode substrate used for Working Example 2–1 was utilized. For the other substrate opposing the electrode substrate, a substrate with a color filter was used. The color filter that was used had a stripe–shaped arrangement of R, G and B. Also, the dimensions of the subpixels were 300μm in longitudinal direction and 90μm in transversal direction. Furthermore, a black matrix was provided between R, G and B, and the height of the longitudinal portion of the black matrix was 1.3μm, whereas the height of the transversal portion of the black matrix was 1.0μm.

Then, a silane–based surfactant was dissolved to a concentration of 0.2wt% in a non–aqueous organic solvent made of thoroughly dehydrated chloroform, thus producing a chemical adsorption solution. For the silane–based surfactant, a surfactant including molecules with the functional groups C_6H_5–CH=CH–CO–C_6H_4–O–CH_2–O–including chalcone groups was used.

Then, sufficiently degreased and rinsed, the electrode substrate and the substrate with color filter were immersed for one hour in the chemical adsorption solution. With this process, it was possible to adsorb the adsorption molecules on the surface of the electrode substrate and the substrate with the color filter.

The electrode substrate and the substrate with the color filter were

retrieved from the chemical adsorption solution, and rinsed under a dry atmosphere. Thoroughly dehydrated chloroform, which is a non–aqueous organic solvent, was used as a cleaning agent. The cleaning time was 10min.

Next, the two substrates were lifted from the cleaning agent under a dry atmosphere. The cleaning agent was removed from the electrode substrate, such that the lifting direction was parallel to the extension direction of the electrodes. In the substrate with the color filter, the lifting direction was parallel to the direction of the longer portions of the black matrix. After the cleaning agent was dried off, the two substrates were retrieved into a regular atmosphere, and reacted with the water content in the air. Thus, monomolecular alignment films were formed.

Then, the alignment films were alignment processed by photoalignment. Polarized UV light was irradiated on the surface of the alignment films such that the polarization direction of the polarized UV light was parallel to the above–described lifting direction (i.e. the extension direction of the electrodes or the direction of the longer portions of the black matrix). The irradiation direction was set to be perpendicular to the substrate surface, and the irradiation was performed for 6sec at an irradiation intensity of $80mW/cm^2$. Thus, the chalcone groups serving as the photosensitive groups were polymerized and the film molecules were crosslinked.

Next, the electrode substrate and the substrate with the color filter were aligned together such that the alignment films were arranged in

opposition to one another, thereby assembling an empty cell. Herein, the alignment processing direction of the alignment film on the electrode substrate and the alignment processing direction on the substrate with the color filter were arranged to be in parallel. Furthermore, a rectangular frame–shaped sealing member was formed by screen printing on the surface of the electrode substrate on which the alignment film is formed. An aperture portion (liquid crystal injection port) was formed by leaving a portion of the rectangular frame shape open. The liquid crystal injection port was arranged at the middle of one side of the rim of the empty cell, such that the aperture direction was parallel to the longitudinal direction of the black matrix. Thus, the liquid crystal injection direction was matched with longitudinal direction of the subpixels (extension direction of the longer portions of the black matrix), the alignment processing direction of the alignment films, and the extension direction of the electrodes. The cell gap was about 4.5μm.

Next, a liquid crystal with positive dielectric anisotropy was injected into the empty cell by vacuum injection, thus forming a liquid crystal cell I in accordance with Working Example 2–15.

<u>Comparative Example 2–15</u>

The comparative liquid crystal cell of Comparative Example 2–15 has substantially the same configuration as the liquid crystal cell in Working Example 2–15, but its manufacturing method differs in that it was produced by injecting the liquid crystal from a direction parallel to a

transversal direction of the subpixels (extension direction of the shorter portions of the black matrix). The liquid crystal cell of Comparative Example 2–14 produced in this manner is referred to as the comparative liquid crystal cell J in the following.

Results

The alignment of the liquid crystal cell I according to Working Example 2–15 and the comparative liquid crystal cell J according to Comparative Examples 2–15 made as described above was evaluated. more specifically, using a polarizer, the liquid crystal cell I and the comparative liquid crystal cell J were examined with the bare eye and through a polarization microscope. The results of this evaluation are listed in the following Table 1–4.

Table 2–7

	liquid crystal injection direction	occurrence of flow alignment	alignment condition	contrast
Working Example 2–15	parallel to longer portions of BM	no	almost no disclinations	295
Comparative Example 2–15	parallel to shorter portions of BM	yes	many disclinations	240

As becomes clear from Table 2–7, it was better possible to arrange the liquid crystal with the liquid crystal cell I in accordance with the present invention in an initial direction according to the alignment processing direction of the alignment film without being influenced by the liquid crystal injection direction than with comparative liquid crystal cell J, and almost no

disclinations occurred in the subpixels of the liquid crystal I. Also, the contrast ratio was higher in the liquid crystal cell I according to the present invention, and it was ascertained that it had an excellent display quality.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The embodiments disclosed in this application are to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are intended to be embraced therein.

INDUSTRIAL APPLICABILITY

The following advantageous effects can be attained with the present invention, realized by the above–described embodiments.

In a liquid crystal display panel with twisted structure according to the first aspect of the present invention, the discrepancy between the liquid crystal injection direction and the alignment processing direction is made small, and alignment in the desired alignment structure is facilitated energy–wise by setting the liquid crystal injection direction parallel or perpendicular to a direction dividing an intersection angle defined by the alignment processing direction in one alignment film and the alignment processing direction in the other alignment film into two equal angles or substantially equal angles. As a result, the advantageous effect is attained that a liquid crystal display panel can be manufactured, in which flow

alignment is eliminated or its occurrence is suppressed.

In another liquid crystal display panel with parallel alignment structure according to the first aspect of the present invention, the discrepancy between the alignment directions of the liquid crystal molecules and the alignment processing directions directly after injection is eliminated, by setting the injection direction of the liquid crystal to be parallel to the alignment processing direction in the pair of alignment films, and the advantageous effect is attained that a liquid crystal display panel can be obtained, in which almost no flow alignment occurs.

In a method for manufacturing a liquid crystal display panel with twisted structure according to the first aspect of the present invention, the sealing member is formed such that the aperture direction of the liquid crystal injection port is parallel or perpendicular to a direction dividing an intersection angle defined by the first alignment processing direction in the first alignment film and the second alignment processing direction in the second alignment film into two equal angles or substantially equal angles, and the liquid crystal injection direction when injecting the liquid crystal material through the liquid crystal injection port in the liquid crystal injection step is parallel or perpendicular to the direction dividing the intersection angle defined by the first alignment processing direction and the second alignment processing direction into two equal angles or substantially equal angles, whereby the advantageous effects can be attained that the injection direction when injecting the liquid crystal is made constant, and a liquid crystal display panel can be manufactured, in

which flow alignment is eliminated or its occurrence is suppressed.

Furthermore, in a method for manufacturing a liquid crystal display panel with twisted structure according to the first aspect of the present invention, the sealing member is formed such that the aperture direction of the liquid crystal injection port is parallel to the first alignment processing direction of the first alignment film and the second alignment processing direction of the second alignment film, and the liquid crystal injection direction when injecting the liquid crystal material through the liquid crystal injection port is parallel to the first and second alignment processing directions, whereby the advantageous effects can be attained that the injection direction when injecting the liquid crystal is made constant, and a liquid crystal display panel can be manufactured, in which flow alignment is eliminated or its occurrence is suppressed.

In a liquid crystal display panel according to the second aspect of the present invention, the liquid crystal injection port is arranged such that a liquid crystal injection direction substantially matches a direction for which, in a projection plane obtained by projecting structural elements inside the liquid crystal layer except for supporting members for holding a predetermined spacing between the pair of substrates in a direction parallel to the substrate plane onto a projection plane, the area of the region taken up by an empty portion, which is obtained by subtracting the projection area of the structural elements from the total projection area, becomes largest. Thereby, the occurrence of flow alignment can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality,

such as contrast.

In a liquid crystal display panel according to the second aspect of the present invention, the liquid crystal injection port is arranged such that the liquid crystal injection direction when injecting the liquid crystal substantially matches the extension direction of the electrodes, so that it is possible to suppress the effect of the electrodes, which pose a flow resistance to the flow of the liquid crystal. As a result, the occurrence of flow alignment can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality, such as contrast.

In a liquid crystal display panel according to the second aspect of the present invention, the liquid crystal injection port is arranged such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of a thickest portion of the light–blocking film of a color filter, so that it is possible to suppress the effect of the light–blocking film, which is a cause for flow alignment. As a result, the occurrence of flow alignment can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality, such as contrast.

In a method for manufacturing a liquid crystal display panel according to the second aspect of the present invention, liquid crystal injection port is formed such that the liquid crystal injection direction matches a direction in which a flow resistance due to structural elements posing an obstacle for liquid crystal flow that are inside the liquid crystal layer, except the supporting members for holding a predetermined spacing

between the pair of substrates, becomes minimal, so that in the liquid crystal injection step, the liquid crystal can be injected with the obstacles to the liquid crystal flow inside the empty cell reduced to a minimum. Thus, the occurrence of flow alignment due to flow resistance can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality, such as contrast.

In another method for manufacturing a liquid crystal display panel according to the second aspect of the present invention, the liquid crystal injection port is formed such that the liquid crystal injection direction when injecting the liquid crystal substantially matches an extension direction of the electrodes, so that the influence of the electrodes, which pose an obstacle to the liquid crystal flow, can be reduced to a minimum. As a result, the occurrence of flow alignment caused by the electrodes can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality, such as contrast.

In yet another liquid crystal display panel according to the second aspect of the present invention, the liquid crystal injection port is formed such that the liquid crystal injection direction when injecting the liquid crystal substantially matches the highest portion of the light–blocking film, so that the influence of the light–blocking film, which poses an obstacle to the liquid crystal flow, can be reduced to a minimum. As a result, the occurrence of flow alignment caused by the electrodes can be decreased, and a liquid crystal display panel can be obtained that has excellent display quality, such as contrast.

Thus, the present invention is of considerable significance for the industry.